The
ENGINEERS' DIGEST
A World Review of
DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT
VOL. XXII No. 12 DECEMBER, 1961

STANLEY HOWARD

INTRODUCES A **NEW**
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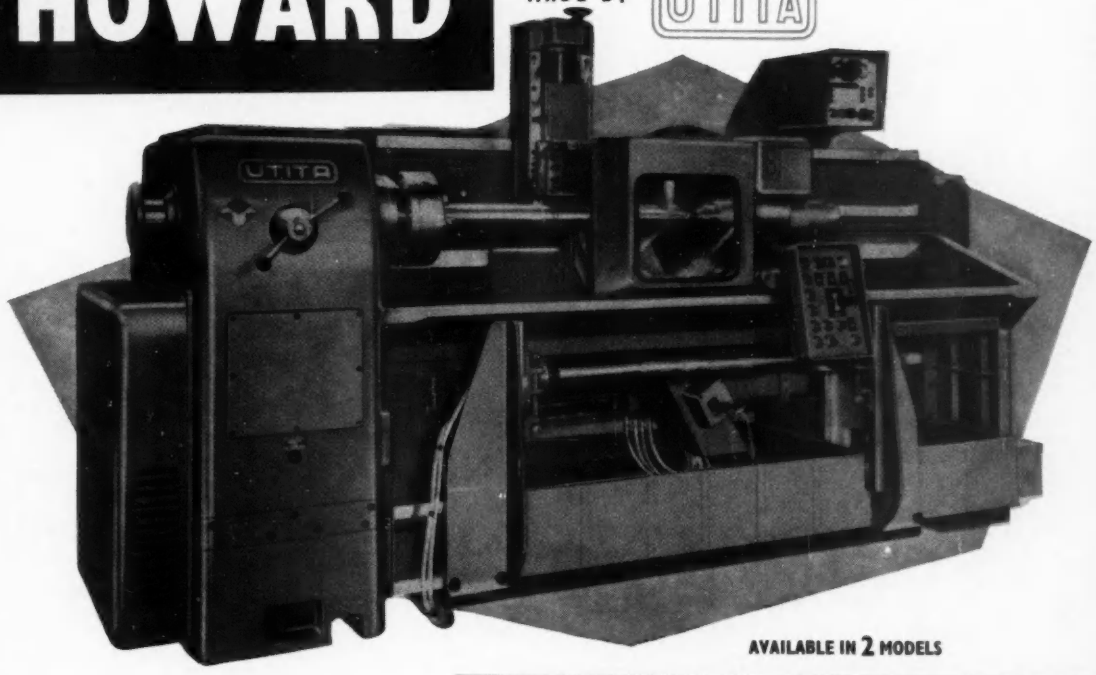

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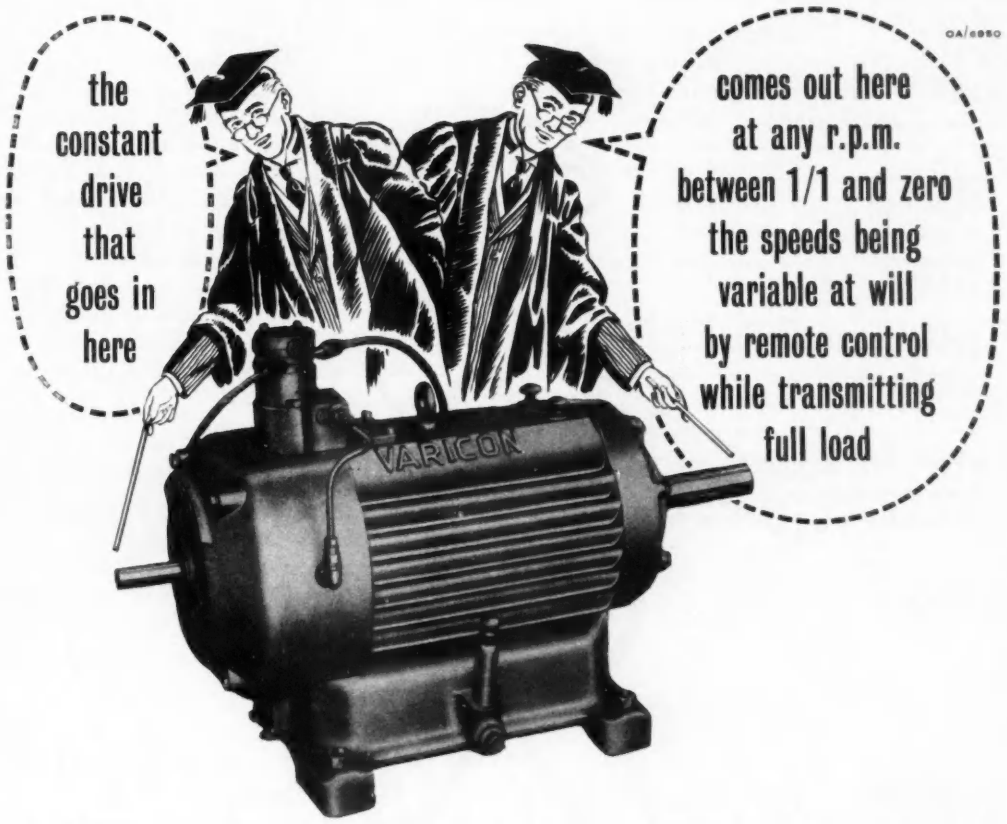
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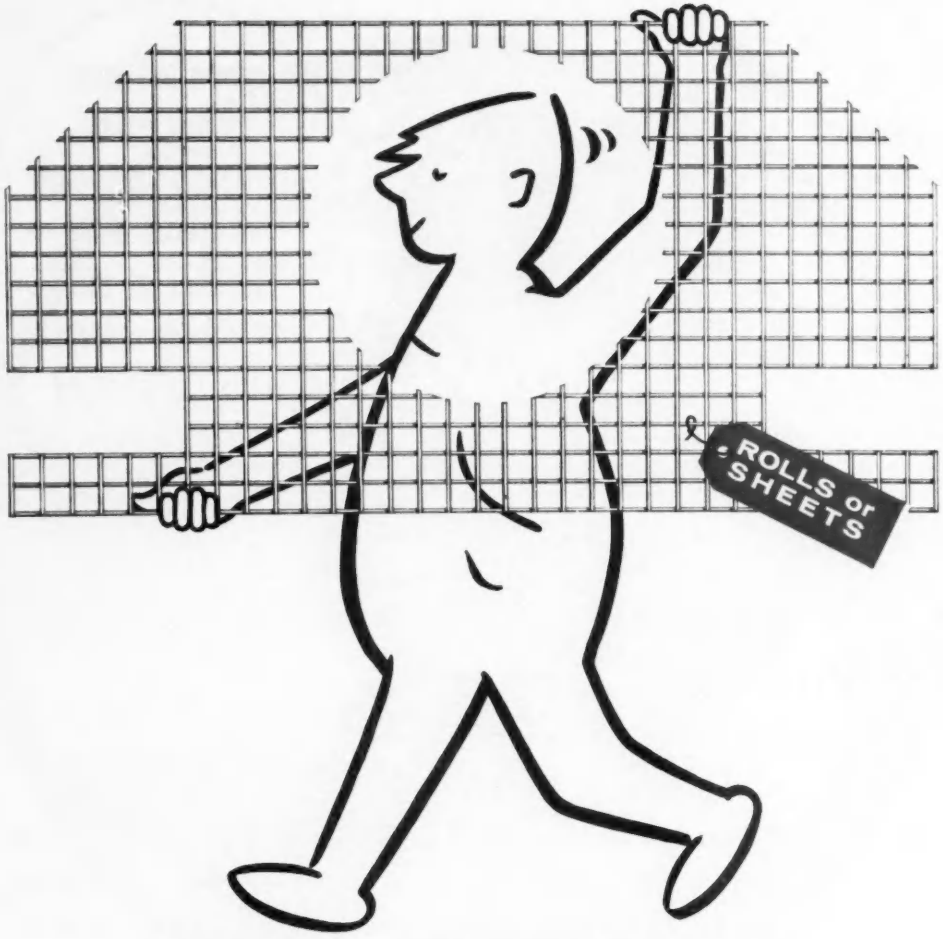

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A World Review of DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

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The MINIDIGEST

Although hafnium and zirconium can in many applications be considered as one constituent, accurate knowledge of their presence is important in some applications, e.g., in nuclear reactors. For this reason, a **new method of separating hafnium and zirconium** has been developed by the National Bureau of Standards, separation for analysis being obtained by the use of a strong quaternary-amine anion-exchange resin column, with dilute sulphuric acid as the eluting solution. It is stated that the new method, which is a practical, single-step chemical procedure, is particularly useful for determining the amount of zirconium in hafnium-base materials.

* * *

According to an article in *The Journal of the Institution of Electrical Engineers of Japan* for April 1961, a new **high-speed magnetographic page-printer for electronic computers** has been developed in Japan. In this printer, the characters are made up of dots registered on a magnetic tape by a rotating seven-channel head, the latent magnetic image then being made visible by dusting with iron powder, which adheres to the dots. This visible image is then transferred to paper coated with wax, which is heated to fix the image. The prototype printer is reported to have achieved a speed of 1200 lines of 30 characters each per minute, but models operating on the same principle are being designed for higher printing speeds.

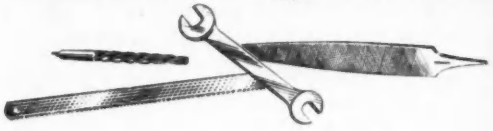
* * *

By using **glass ultrasonic delay lines for high-speed digital computers and data-processing equipment,** serial memories have been built which exhibit information rates of from 3,000,000 to 20,000,000 bits per second, i.e., comparable with those of thin-film, cryogenic, and tunnel-diode memory devices. Delay times as high as 150 microseconds have been achieved with this type of delay line, which was developed by Corning Electronic Components and which uses a special Corning glass with a nominal time-delay temperature coefficient of zero.

* * *

Details of a new **process for combining metals with graphite** are given in *Mechanical Engineering* for September 1961. The process makes it possible to combine such metals as iron, nickel, copper, silver, cobalt, and their alloys with from 10 to 90% of graphite, provid-

So as to give an



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ing intimate bonding between the metal and graphite and giving improved mechanical and electrical properties. It is stated that the usual brittle characteristic of graphite is greatly reduced in some compositions and is actually eliminated in others. Some compositions of graphite and steel can be heat-treated by conventional methods. According to present indications, little, if any, machining will be required on final components, and the material is malleable enough to be sized in production equipment at high speed, even to exceptionally close tolerances. Typical applications of these materials, which appear to have a transverse rupture strength up to 50,000 psi and a compressive strength up to 120,000 psi, are envisaged in self-lubricating bearings, electrical brushgear and contacts, seals, and resistance elements.

* * *

As reported briefly in *Electronics* for September 15, 1961, a new **closed-circuit television comparator** makes it possible to inspect in minute detail such components as transistors, resistors, micro-miniature wafers, and sub-assemblies, as well as live biological specimens, etc. The comparator has a range of magnification up to ×300 and, by means of a control stick, the operator can position the image, as desired, on the screen and can also change its magnification throughout the entire range without any loss of focus.

* * *

Details are given in *Svarochnoye Proizvodstvo* for September 1961 of comparative tests carried out in Russia in connection with the **arc-welding of copper under shields of argon or nitrogen,** using copper specimens measuring 160 × 80 × 12 mm thickness, tungsten electrodes, and welding currents of 400 to 460 A and 15 to 39 V. When welding copper by the inert-gas-shielded arc process, the use of argon is generally recommended, but the results of these tests seem to indicate that, quite apart from its comparative cheapness, nitrogen permits a greater degree of heat transfer than argon and increases the efficiency of the welding process by from 20 to 30%.

* * *

Still in the experimental stage, **ultraminiature transistors** developed by the Radio Corporation of America are so small that 20,000 of them could fit on a postage stamp and could make it

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possible to produce on a surface only twice as wide as a human hair a complete three-stage amplifier, including thin-film transistors and their connections. The new transistors are made by depositing by evaporation thin films of cadmium sulphide and metal on an insulating base. This technique ties in with current methods of making thin-film devices of other types and indicates the possibility of the low-cost mass production of entire transistor circuits containing hundreds of elements.

* * *

It is reported by the Aerospace Department of the Westinghouse Electric Corporation that a **possible new source of power** has been found and involves the heating of a metal-ceramic sandwich comprising two thin plates in which an iron-base metal is covered with porcelain enamel and a thin layer of silver. It is stated that each plate produces power densities up to 16 mW/sq in. when heated to 1200°F, the iron acting as the positive pole and the silver acting as the negative pole.

* * *

Details are given in an article in *Acta Technica Academiae Scientarum Hungaricae* (Nos. 1-2, 1961) of a **method of revealing the austenitic grain size of hardenable steels** by means of the relief formed during martensitic transformation. In this technique, two polished samples are held together in good contact and are then heated in an inert atmosphere and quenched. When the samples are separated, the grain size of the austenite on the polished contacting surfaces is clearly visible for microscopic examination without any further preparation or etching. If, however, the samples are etched, some details of the formation of martensite and of the relation of martensite needles to the austenite are also rendered visible.

* * *

As described briefly in *Machine Design* for November 9, 1961, a **new method of controlling the output speed of large variable-speed drives** involves the use of a mechanical closed loop, in which a small differential-gear set measures the difference between the output speed and a reference speed, this error signal actuating the control spindle of the drive. A small variable-speed drive is incorporated to provide control of the reference speed.

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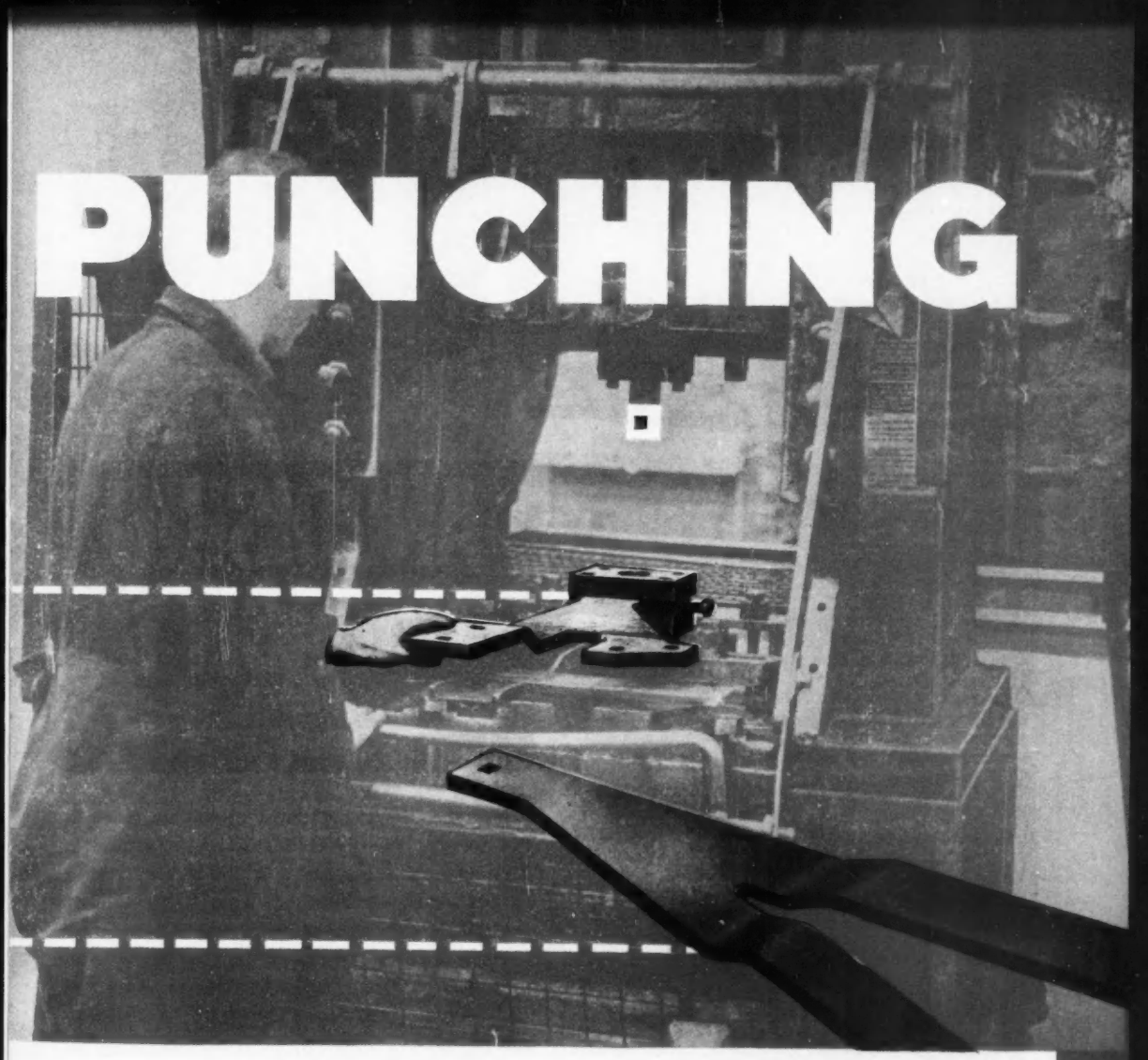

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BUSINESS NOTES

It is announced by **The A.P.V. Co. Ltd.** and **A.P.V.-Paramount Ltd.**, of Manor Royal, Crawley, Sussex, that their telephone number has now been changed to Crawley 27777.

* * *

Goodenough Pumps Ltd., of London, S.W.1, have acquired the controlling interest in **Silas Hyde Ltd.**, of Birmingham, manufacturers of industrial ovens, conveyor stoving plant, ventilation systems, and dust- and fume-removal plant, and specialists in general sheet-metal work, light and heavy fabrications in mild steel, stainless steel, aluminium, etc.

* * *

An agreement has been concluded between **Elcontrol Ltd.**, of Hitchin, Herts., and **The Siegler Corporation, Magnetic Amplifiers Division**, of New York, for the exclusive sale and manufacture by the latter company of Elcontrol products in the U.S.A. and Canada.

* * *

It is announced by **George Meller Ltd.**, of 24 Fitzjohn's Avenue, London, N.W.3 (Tel: HAMpstead 1344), that they have been appointed sole U.K. representatives and agents for the **Coppus Engineering Corporation**, of Worcester, Mass., who produce a series of vertical and horizontal turbines with ratings of from 1 to 250 hp to suit almost any steam conditions and with a wide range of output speeds.

* * *

The assets and liabilities of **Owen & Dyson Ltd.** have now been transferred to **The United Steel Companies Ltd.** The business of Owen & Dyson is now being undertaken by **Steel, Peech & Tozer**, and the new department thus created will be known as the Fullerton machine shops.

* * *

It is announced by **The Brockhouse Organisation** that their activities in the plastics field, which are at present concerned with the manufacture of injection-moulding machines, have been wholly transferred from their premises at Penn Road, Wolverhampton, to **J. Brockhouse & Co. Ltd.**, of Denton Works, Saxon Street, Denton, Manchester, to whom all correspondence and enquiries should be addressed. The works at Wolverhampton will, however, continue to be concerned with general machining work and with machine-tool manufacture and rebuilding.

* * *

Ferranti Ltd. have agreed to purchase for £440,000 the electricity business of **Aron Meters Ltd.**, including their manufacturing tools and equipment. Ferranti, who are at present the largest manufacturers of meters in Great Britain, have also agreed to undertake Aron commitments for spare parts, maintenance, and meter repairs, to ensure that full provision is made for the working life of all Aron meters in service. To avoid confusion, Aron propose to change the name of their company to **Astaron Electronics Ltd.**, releasing the name of Aron Meters Ltd. for use by a newly formed sub-

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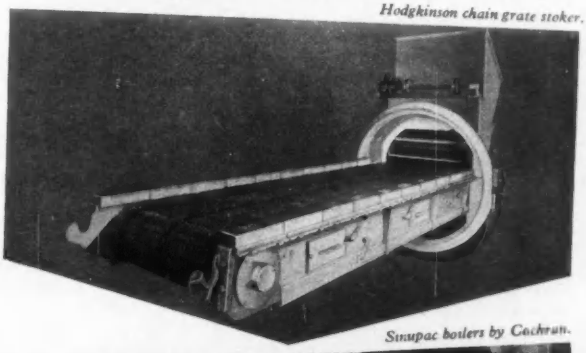
A tonnage equivalent to the entire output of a colliery will be consumed by the new British Motor Corporation factory now being erected at Bathgate in Scotland. The B.M.C. choose coal, because coal has proved the most economical fuel for their purpose, because coal is home-produced and unaffected by policy changes abroad, and because our coalfields can produce all the coal British industry will need for many generations to come.

A view of Whitrigg Colliery.

...will be fed...

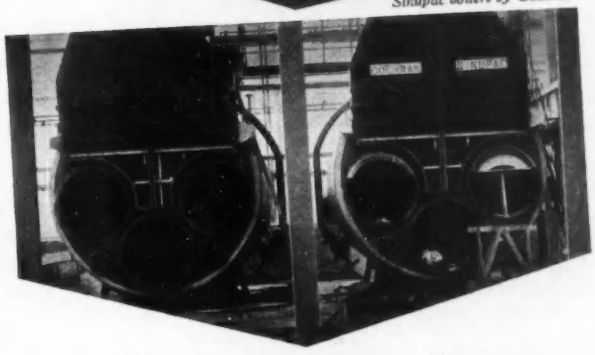
Hodgkinson new design Mark V chain grate stokers are being installed by B.M.C. for maximum thermal efficiency. These stokers maintain a flexible heat control, burn coal smokelessly and can cope rapidly with fluctuating loads.



Hodgkinson chain grate stoker.

...into these...

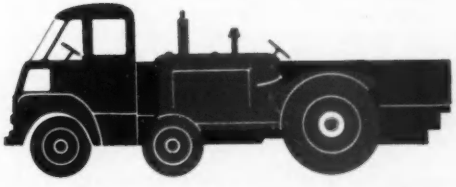
Five high pressure automatically controlled, hot water Cochran 'Sinupac' boilers will each burn (per hour) 1.8 tons of untreated smalls containing 40 per cent. fines. B.M.C. choose Cochran because, even with this low-grade coal, the efficiency will be approximately 80 per cent. on the gross C.V. The total capacity of the five boilers is potentially 160,000,000 B.T.U.'s per hour. This will increase when the factory is in full production.



Sinupac boilers by Cochran.

to power the factory that makes these...

The new B.M.C. factory—an important landmark in the industrial progress of Scotland—will produce approximately 400 tractors and 1,000 commercial vehicles a week, and will employ some 5,000 to 6,000 people. This new B.M.C. factory burning British coal automatically fired by Hodgkinson stokers in Cochran boilers, will increase Britain's prosperity at home —and British trade overseas.



BMC DRIVE AHEAD WITH COAL, HODGKINSON AND COCHRAN

BUSINESS NOTES

sidiary of Ferranti. Under their new name, Aron will expedite the move to their new factory at Aylesbury, where production will be supplemented by an entirely new range of products not allied to the meter industry.

* * *

Walker Crosweller & Co. Ltd., of Cheltenham, manufacturers of "Leonard" thermostatic mixing valves, have recently formed a subsidiary marketing company in Belgium. The new company, **Walker Crosweller S.A.,** of 65 Rue Montagne-aux-Herbes-Potagères, Brussels, is a wholly owned subsidiary of the British company, and its chairman and managing director is Mr. R. Walker, who is managing director of the parent company. Other directors of the Belgian company are Mr. D. L. Launchbury and Mr. C. F. Taylor, who are also on the board of the parent company. The general manager is Mr. G. Dooms, who was previously associated with the firm's Belgian agents.

* * *

A comprehensive range of low-heat-input metal-joining alloys is being marketed by a new company, **Welding Improvements Ltd.,** of Lady's Lane, Northampton, under the trade name of "Fontargen". These alloys, which are already used in Europe, will be sold in the U.K. and Ireland through technically trained representatives and through a number of regional stockists (to be announced later). Dr. H. E. Zentler Gordon and Mr. E. Hindson have been appointed directors of the new company, while Dr. G. M. Blanc, of Zurich will act in a consultative capacity.

* * *

Following negotiations between **Joseph Lucas Limited,** of Birmingham, and **T. V. Sundaram Iyengar & Sons (T.V.S.),** of South India, a partnership agreement has now been signed, initiating the formation of a new company to be known as **Lucas-T.V S. (Private) Ltd.** The new company will manufacture a wide range of electrical equipment for vehicles to meet the demands of the rapidly expanding Indian motor industry. The capital of the company in the early years will amount to over £2,000,000, including more than £1,000,000 worth of plant and machinery provided by Lucas.

* * *

It is announced by **Chilton Electric Products Limited,** of Hungerford, Berks., that they have signed an agreement with the **Westinghouse Electric Corporation,** whereby they become exclusive manufacturers of Westinghouse moulded-case circuit-breakers in the U.K., with non-exclusive sales rights for the rest of the world (with the exception of the U.S.A. and Canada). Initially, these circuit-breakers will be imported from the U.S.A. and modified at the Chilton factory until full-scale production begins.

* * *

Bergen Tempered Ltd., a member company of the **Tempered Group,** have moved to new premises with increased space and production facilities in Sussex Road, Sheffield 4.

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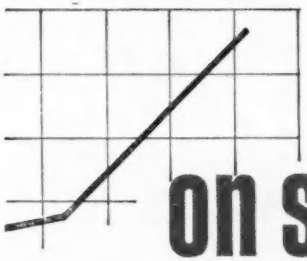

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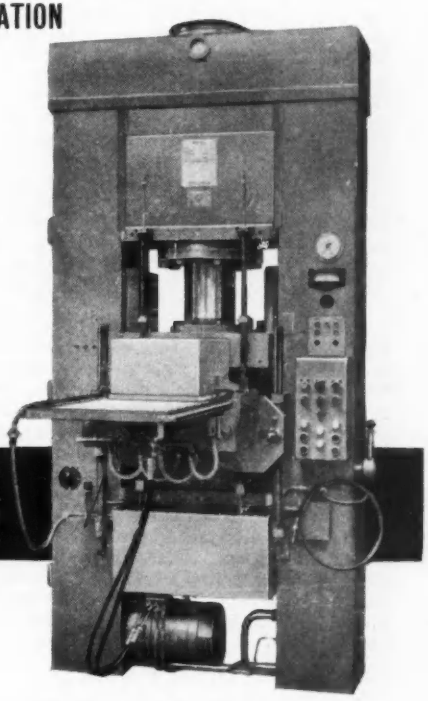

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CONTRACTS

An order, valued at £75,000, has been received by Lightnin Mixers Ltd., of Poynton, Cheshire, from the Polymer Corporation, of Reading, Penn., for the supply of fluid mixers. These units will provide the main mixing requirements for a new plant which the Polymer Corporation is setting up in Strasbourg, and it is expected that they will be delivered early in 1962.

* * *

A comprehensive contract for a 120-MW extension to the Cairo South Power Station has been awarded to The English Electric Co. Ltd. by the Cairo Electricity and Gas Administration. The existing generating plant is of Continental manufacture, and the new order, valued at £6,000,000 and one of the largest for British industry in the Middle East since 1957, was obtained in the face of keen competition from Czechoslovakia, France, Germany and the U.S.A., as well as from other British firms. The order covers the complete electrical and mechanical equipment for supplying a further 120 MW for domestic and industrial use in Cairo, and includes boilers, turbo-alternators and auxiliary equipment. The two 60-MW steam turbines involved will be made at the Rugby works of English Electric, while the alternators, transformers (including two rated at 75 MVA), and the 63-kV switchgear will be made at Stafford, and the low-voltage switchgear and fusegear at Liverpool. The four boilers, each with a capacity of 441,000 lb/hr, will be manufactured by Simon-Carves Ltd., of Stockport.

* * *

Associated Electrical Industries Limited have been awarded a contract worth £178,000 by the East Midlands Electricity Board to reinforce the supply between North Wilford generating station on the outskirts of Nottingham and a new substation at Isandula Road, Nottingham. The contract will be carried out by the AEI Construction (Cables and Lines) Division and will involve the supply of materials for and the erection of nearly a mile of double-circuit 132-kV overhead power line on six towers of J. L. Eve design, as well as the supply, installation, and jointing of two 4100-yard lengths of three-core, oil-filled 132-kV underground cable and associated pilot and telephone cables and accessories. The cable for the underground part of the project will be manufactured at the Woolwich and Gravesend factories of the AEI Cable Division.

* * *

A contract, valued at £330,000, has been received by the British Insulated Callender's Cables Group of Companies from the Central Electricity Board of the Federation of Malaya for the supply and installation of some 60 miles of power, control, and telephone cables for the Cameron Highlands hydro-electric scheme. This order, which is one of the largest of its kind ever to be awarded by the Central Electricity Board of Malaya, includes about 3 miles of 132-kV power cable to be installed in an inclined shaft to an underground power station, about 26 miles of 11-kV power cable, 4 miles of 660/1100-V paper-lead and P.V.C.-insulated power cables, and about 27 miles of control, telephone, and coaxial cables. The site work will occupy approximately 18 months, the contract being scheduled for completion by August 1963. The Cameron Highlands hydro-electric scheme involves 15 miles of tunnelling work and the construction of a dam, 120 ft high, three diversion weirs, and two power stations, which will use the waters of the rivers Bertam and Telom. The larger station will be located underground at Jor, about 90 miles north of Kuala Lumpur, and will eventually house four 25-MW generating sets operating under a gross head of 1880 ft of water. The smaller station, to be located at Habu, 6 miles north-east of Jor, will accommodate two 2·75-MW sets.

* * *

Turbo-generating equipment for a large Argentine textile mill has been ordered from W. H. Allen Sons & Company Ltd., of Bedford, by Sociedad Anónima Castelar, of Buenos Aires. In addition to generating electrical power in parallel with existing diesel-alternator sets, the equipment will provide process steam for treating the raw cotton used in manufacture. The turbine will comprise an Allen pass-out condensing set of 400-kW capacity, driving through an Allen top-pinion, parallel-shaft speed-reduction gearbox a 1500-rpm Mather & Platt alternator, supplying power for a 380-V, three-phase, four-wire, 50-cps system at a power factor of 0·8. The machine will be supplied complete with a self-contained condenser, and the steam conditions will be 176 psig and 571°F, with from 8,000 to 13,000 lb/hr of steam available for processing at 40 psig, the balance going to the condenser at a nominal vacuum of 27·5 in. Hg.

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UHS1

PERSONAL

The United Steel Companies Limited announce that **Mr. R. G. Monkhouse,** manager of their Workington Iron and Steel Company branch, has been appointed works manager (Ickles) at their Steel, Peech & Tozer branch.

* * *

Associated Electrical Industries Ltd. announce that **Mr. A. C. Main, B.Eng., M.I.E.E., M.I.Mech.E.,** has been appointed a director of manufacturing services. This appointment ensures the co-ordination of manufacture throughout A.E.I., and Mr. Main will be responsible for the constant review of the standard of manufacturing services and techniques, the supply of trained and qualified staff in all the factories of the company, and the co-ordination of factory planning and capital expenditure in the manufacturing sphere. He will also represent the company in its relations with the employers and labour organizations.

* * *

Elliott Brothers (London) Limited, a member of the Elliott-Automation Group, announce that **Mr. A. C. Jones, A.M.I.Mech.E., A.M.Inst.Fuel,** has been appointed an assistant general manager within the Automatic Control Valves Group.

* * *

Commander A. B. Dickie, A.M.I.Mech.E., M.I.Mar.E., and **Mr. F. H. Stimson** have been appointed assistant directors of Newman Hender & Co. Ltd., of Woodchester, Stroud, Glos., manufacturers of industrial valves and allied products. Commander Dickie, head of the Newman Hender Group Research and Development Division, will continue to act as director of this division, while Mr. Stimson, who has been deputy to the sales director, will continue in his present field as assistant director of sales.

* * *

Mr. L. H. Welch, O.B.E., B.Sc.(Eng.), M.I.E.E., who retired recently from the position of chief electrical engineer to the London Electricity Board, has been appointed industrial-relations consultant to the Electrical Research Association.

* * *

The Firth Cleveland Group of companies announce that **Mr. W. H. Rigg, B.Sc.,** has been appointed managing director of Firth Cleveland Tools Ltd., a member of the Group, and will operate from the company's Tipton works in Staffordshire.

* * *

It is announced by Tecalemit Ltd., of Plymouth, that **Mr. T. C. Worth** has been appointed a director of the company.

* * *

As announced by Holden & Brooke Ltd., of Manchester 12, **Mr. R. A. Brooke** has relinquished the position of works director and has assumed responsibility as commercial director, while **Mr. F. L. Taylor** has been appointed to the new post of production controller, his previous duties in connection with sales matters now being undertaken by **Mr. M. Beesley.** In addition, **Mr. S. N. Clift** has retired from his position as Northern Area outside sales manager and has been succeeded by **Mr. S. K. Hallworth.**

* * *

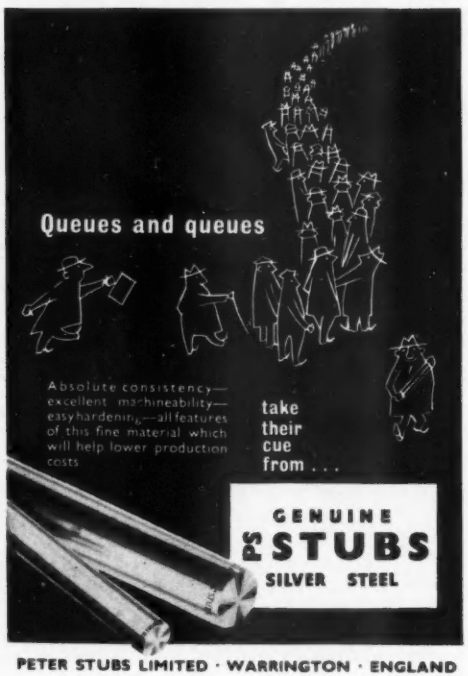
As announced by The Plessey Co. Ltd., **Mr. R. Hall** has been appointed divisional general manager of a total of four divisions and associated companies within the Plessey Swindon Group, comprising the Units and Parts Division and Sheet-Metal Unit of the Plessey Co. Ltd., as well as Power Auxiliaries Ltd. and Machine Products Ltd. Mr. Hall was previously commercial executive for the Swindon region.

* * *

Dewhurst & Partner Limited, of Hounslow, announce the appointment of **Mr. E. Trattles** as Western Area sales manager, to operate from the company's Gloucester office at 56-58 Barton Street, Gloucester (Tel: Gloucester 25613).

* * *

It is announced by Stanley Works (G.B.) Ltd. that **Mr. A. G. Jones,** general works manager, has been appointed works director, while **Mr. W. R. Mills,** general sales manager, has been appointed sales director. **Mr. W. M. Dingley** has relinquished his seat on the board as a result of his increasing commitments as director of marketing in Europe for the whole of the Stanley international organization.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NEWS ROUND-UP

The New Ferranti Electronics Laboratory

Intended to house their Applied Electronics Department, the new electronics laboratory recently opened by Ferranti Ltd. at Silverknowes, Edinburgh, is an attractively designed three-storey building with approximately 35,000 sq ft of floor space allocated to fully equipped laboratories, a drawing office, a development workshop for translating initial ideas into accurately machined items during the early design stages, an installation bay, 30 ft in height, for assembly of mobile radar, and an administration area. Permanent internal walls have been kept to a minimum, specially designed demountable partitioning being used throughout to provide flexibility of layout. In fact, although the building has been constructed for a specific purpose, it is considered that there is sufficient flexibility to adapt accommodation, if required, to suit the ever-changing needs of the department. Another feature is the use of acoustic-type ceilings which reduce noise level in the building to almost infinitesimal proportions.

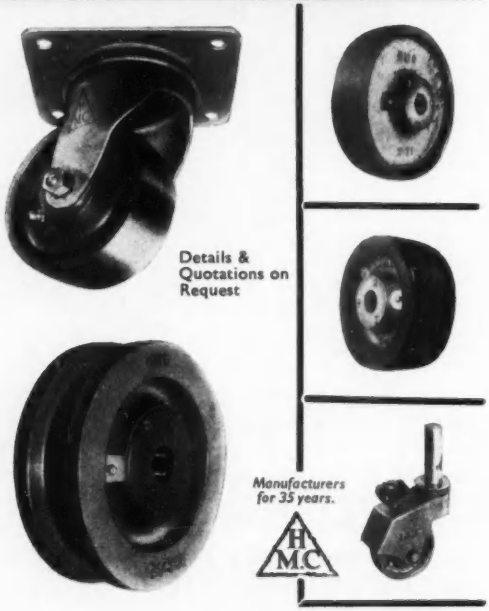
The Applied Electronics Department is mainly concerned with the development of radar and other systems for the Services for both airborne and ground use, but various non-military projections are also being undertaken for the benefit of many of the major industries in the U.K. This work involves the theoretical study and practical application of the generation, transmission, and reception of frequencies ranging from only a few cycles per second to tens of thousands of megacycles per second.

Film on Tool and Die Steels

During 180 years of Sheffield steelmaking, William Jessop & Sons Limited have been noted for their enterprise and the achievement of important metallurgical developments, while J. J. Saville and Company Limited, also with a fine record of tool-steel production, were prominent in the early improvement of high-speed steels. To-day, Jessop-Saville Ltd., a member of the B.S.A. Group, manufacture an extraordinarily wide range of steels to cater for virtually every requirement, including carbon and alloy tool steels, die steels, high-speed steels, hot-work steels, constructional steels, case-hardening and nitriding steels, heat-resistant and creep-resistant steels, corrosion-resistant and stainless steels, vacuum-melted steels, constructional steels, and high-speed toolbits, as well as titanium and zirconium alloys, files and rasps, and permanent magnets.

Of these products, alloy tool and die steels form a considerable and technically very important group in the production of the Jessop-Saville organization. This group comprises a very wide range of qualities, from low-alloy compositions for use as coining, cutlery, and cold-heading dies, to specialized types for heavy-duty applications, including dies for hobbing, thread-rolling, deep-drawing, and pressing. The ever-increasing demands of the engineering industry for improved materials have created a need for superior steels for forming and shaping tools, and it is the object of the new Jessop-Saville film "Tool and Die Steels" to show the applications of these steels and the processes involved in their manufacture. The film opens with shots of a series of operations showing the use of tool steels in a variety of

WHEELS & CASTORS FOR INDUSTRY



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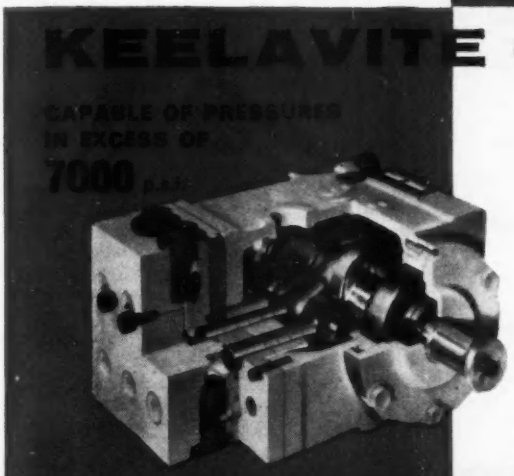

The new Keelavite/Gury fixed capacity piston pumps are capable of maximum pressures of as high as 5700 p.s.i. for continuous running or, in excess of 7000 p.s.i. for intermittent use.
Capacities range from 0.43 g.p.m. to 44 g.p.m. at 1500 r.p m. The design and construction of these units give exceptionally silent operation and extremely long life.

Specification of a few of THE K.G. SERIES OF PISTON PUMPS

Type	Bore/ Stroke	Flow in g.p.m.		Cont. Service at 1500 r.p.m.		3rd Service at 1500 r.p.m.		1/10th Serv. at 1500 r.p.m.		Wt.
		1000 r.p.m.	1500 r.p.m.	max. pr. p.s.i.	Input H.P.	Max. pr. p.s.i.	Input H.P.	Max. pr. p.s.i.	Input H.P.	lb.
GVS		0.28	.43	5700	2	6500	2.5	7100	3	62
GV6	12.12	0.8	1.21	6000		6750		7100		62
	14.12	1.1	1.65	4600	6	5400	7.5	6000	8	62
	16.12	1.47	2.2	3600		4300		5000		62
GV15	16.15	1.87	2.76	5700		6500		7100		86
	18.15	2.32	3.53	4600		5460		6000		86
	20.15	2.97	4.4	3600	12	4390	15	5000	17	86
	20.20	3.97	5.83	3000		3600		4000		86

The above figures refer to the three smallest pumps in the KG range. Altogether there are nine sizes, and by varying the stroke/bore dimensions twenty-two different ratings are available. Double pump units are made up to fulfil specific requirements. Literature giving full particulars will be sent on request.

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applications, such as hot extrusion, hot stamping, pressure diecasting, plastics injection-moulding and compression-moulding, and cold-forming and trimming and sheet metal. It then traces the sequence of the manufacture of these steels, covering the melting of the steel, the numerous hot-working and testing operations involved, including the repeated analysis of samples to ensure consistent quality, and the inspection of the finished product, together with a short sequence demonstrating how blocks of steel are transformed by the toolmaker into intricate dies and moulds. Well-photographed in colour, some of the shots showing the reduction by roll-cogging of ingots to billets and their further reduction in rod, bar, or sheet mills are exceptionally well conceived. Equally impressive are the scenes of specialized high-alloy steels being reduced from the ingot by power hammers and close-ups of the upsetting of steel blooms under a forging press.

The film (16-mm, colour, with optical sound track) has been entirely produced within the Jessop-Saville organization and has a running time of 25 minutes. Copies are available on free loan, but should be booked in advance for screening on a specific date. All enquiries should be addressed to The Publicity Department, Jessop-Saville Ltd., Brightside Works, Sheffield.

Machine-Tool Trades Association Design Scholarships

Early in 1959, the Machine-Tool Trades Association announced a plan to sponsor advanced specialized education in machine-tool design, taking the form of a two-year full-time course, of post-graduate standard, at Manchester University. Essentially, the course is intended for young men who are already in the industry and who show evident aptitude for design. The scheme is now in its third year, and, on December 1, 1961, the first group of students qualified for the award of A.M.C S.T. and have now returned to the industry.

A feature of the course is that students are engaged during their vacations on projects under conditions different from those of their previous experience. In fact, those who have just graduated have undertaken a period of industrial experience with various machine-tool manufacturers on the Continent. The course is designed to cater for students with varying qualifications on admission. Thus, it has met the needs of the industry in two ways. In the first place, there are entrants aged about 30, who have already worked in machine-tool design offices, who have served an engineering apprenticeship, and who have attained the standard for graduate membership of an engineering institution. For such students, the course serves to broaden their education, so that their academic ability becomes at least of university graduate level, with a specialized bias. In the second place, there are students who already hold first degrees in engineering, but with relatively less industrial experience. For these students, the course is in every way post-graduate.

The London International Engineering Exhibition

To meet changing European trading conditions, the long-established Engineering, Marine, Welding, and Nuclear Energy Exhibition is to be transformed into a huge international exhibition, using the 1,000,000 sq ft of both Olympia and Earls Court, London, so that the stand area will be doubled. The new exhibition, to be known as The London International Engineering Exhibition, will take place from April 23 to May 2, 1963, and has been timed to overlap partly the Hanover Fair in West Germany, so that buyers from all over the world will be able to see both these events in one short visit to Europe. This will be the first occasion on which both Olympia and Earls Court have been used together for an international exhibition, and a total of some 1200 exhibitors is expected to take part. The joint organizers are F. W. Bridges and Sons Ltd., who have been responsible for running the Engineering, Marine, Welding, and Nuclear Energy Exhibition since its inception in 1906, and Trade Fairs Ltd., who organized the successful British Trade Fair in Moscow earlier this year. It is stated that the exhibition will be backed by the largest publicity campaign ever launched in support of an International Exhibition held in London.

The exhibition will cater for every type of engineering product, ranging from the largest items of capital equipment to the smallest power tools and components. Olympia will, in general, feature the heavier exhibits, including a welding section (an exhibition in itself), while Earls Court will display electrical-engineering equipment and a range of lighter products. Government information stands will be limited to 1000 sq ft each and are expected from a number of European and other countries.

Classified Advertisements

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Joseph Lucas Research Fellowship

(Preference will be given in this instance for proposals concerning Machine Tool Technology).

Salary range £1300 to £1500 per annum.

This is a major award demanding high qualifications and tenable normally for two years, with possible extension to three years.

College Research Fellowship

Salary range £700 to £1150 per annum.

College Research Assistantship

Salary range £600 to £650 per annum.

Application forms and full details of these posts may be obtained from the Bursar, Room 40, College of Advanced Technology, Gosta Green, Birmingham 4.

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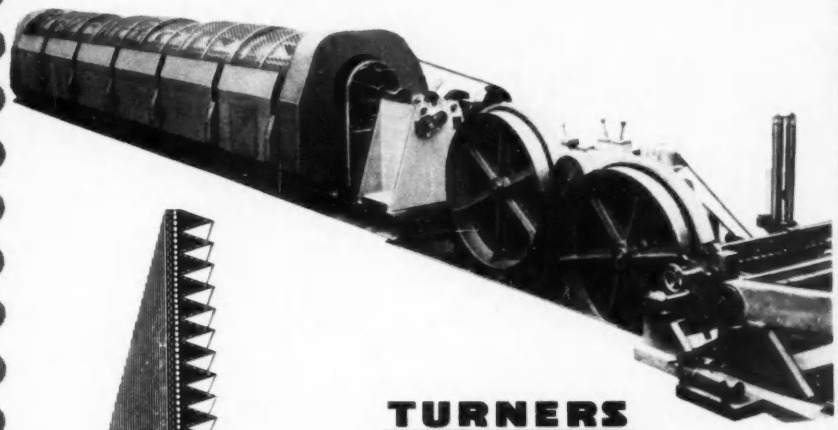

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NEW TECHNICAL BOOKS

Operational Electricity. By Charles I. Hubert. 539 pp., 380 illustrations. Publishers: John Wiley & Sons Ltd., Gordon House, Greencoat Place, London, S.W.1. Price: 68/–.

Based on a total of eighteen years of teaching experience in electrical engineering, a critical appraisal of traditional presentation has been made by Professor Hubert. As a result, he has adopted a highly original and effective sequence which enables students to absorb material more efficiently and quickly. Thus, by considering his subject matter in terms of a single unified course, he has made it possible to arrange the topics concerned to better advantage from the point of view of teaching, and also to eliminate a considerable amount of the duplication inherent, but unavoidable, in traditional methods of presentation. For instance, he concludes that the fundamental laws apply equally to both a.c. and d.c. systems, and that direct current is merely a special case of alternating current at zero cycles per second. Consequently, he feels, with justification, that separation of the two types of currents into two virtually distinct subjects is not academically justified, and does not treat them as such.

Dealing with the theory, characteristics, applications, and mode of operation of circuits and machines, this excellent book combines applicable operating techniques with incisive treatments of the parallel operation of generators, the selection and application of motors and controls, magnetic controllers, and regulators. It should also be noted that the text is arranged for two levels of instruction, this being achieved by blocking off the more complex derivations of those formulae which are not essential to a basic understanding of electrical theory. In this way, additional interest is provided for the faster students, without confusing and slowing down students who are less well-grounded in the requisite physics and mathematics.

The Directory of Opportunities for Graduates, 1962. Edited by Clive Labovitch, M.A. 368 pages. Publishers: Cornmarket Press Ltd., 86–88 Edgware Road, London, W.2. Price: 8/6.

There is no shortage of demand for the services of graduates in industry and elsewhere. Indeed, the number of companies and organizations recruiting graduates has shown a marked increase. Thus, when the first national edition of this directory was published in 1957, there were 186 companies included. In this 1962 edition, no less than 415 industrial and commercial organizations and government departments are listed.

Perhaps because of the wide field of opportunities currently available, graduates seeking worthwhile employment are faced with a number of basic problems. What firm is most likely to use and develop my particular talents? What company offers me a choice of employment in different fields of interest to me? What are my prospects of advancement? What is my initial salary likely to be? These questions, and many others, can normally be answered only by laborious culling of the *Situations Vacant* columns in the daily press or by the hit-and-miss tactics of personal application to firms or organizations which the graduate hopes may have something suitable to offer him.

This directory takes care of all these questions in its stride by providing graduates with up-to-date and pertinent information about the firms which require his services and about the opportunities open to him. All relevant data are given, including a brief history of the firm concerned and its activities, the types of graduate required, prospects, pensions and amenities, details of the locality, and salaries (it is interesting to note in this connection that, in 1957, the average starting salary for a graduate joining a company as a trainee was about £550, as compared with about £700 to-day). In addition, a classified index is included, summarizing in tabular form information about the size of the organizations concerned, whether men and/or women are employed, areas in which employment is offered, etc.

In short, this directory, like its companion volumes, "Directory of Opportunites for School Leavers" (published annually in January), and "Directory of Opportunities for Qualified Men" (published annually in April), is a valuable friend and counsellor and may well save graduates much disappointment and even heart-ache by guiding them on the path to a suitable career.

Digital Data. By D. S. Evans, M.I.E.E. 82 pp., 63 illustrations. Published by Hilger & Watts Ltd., 98 St. Pancras Way, London, N.W.1. Price: 15/–.

Fundamentally concerned with the derivation and reduction of digital data for analysis and process, this excellent book, though small in size, manages to include a wealth of pertinent information on incremental scales, shaft-driven digital devices, direct reading from coded scales, ancillary equipment, and system arrangements and applications, as well as selected bibliography and a useful cross-referenced index.

The contents are presented in a concise and clear manner and are enlivened by a large number of illustrations. In short, for those desiring an insight into the use of data-handling equipment and the principles of digital instrumentation, this book fills a definite requirement as an introduction to a subject which is rapidly assuming an ever-increasing importance.

CHAPMAN & HALL

Principles of Vacuum Engineering

M. PIRANI & J. YARWOOD

A wide coverage of all aspects of vacuum technology and its applications, with the emphasis on practice rather than on theory. Very full details of practical procedures and equipments are given and the industrial applications of vacuum are dealt with to a greater extent than in any other British book. *Illus.* 105*s.*

Engineering Materials Science

C. W. RICHARDS

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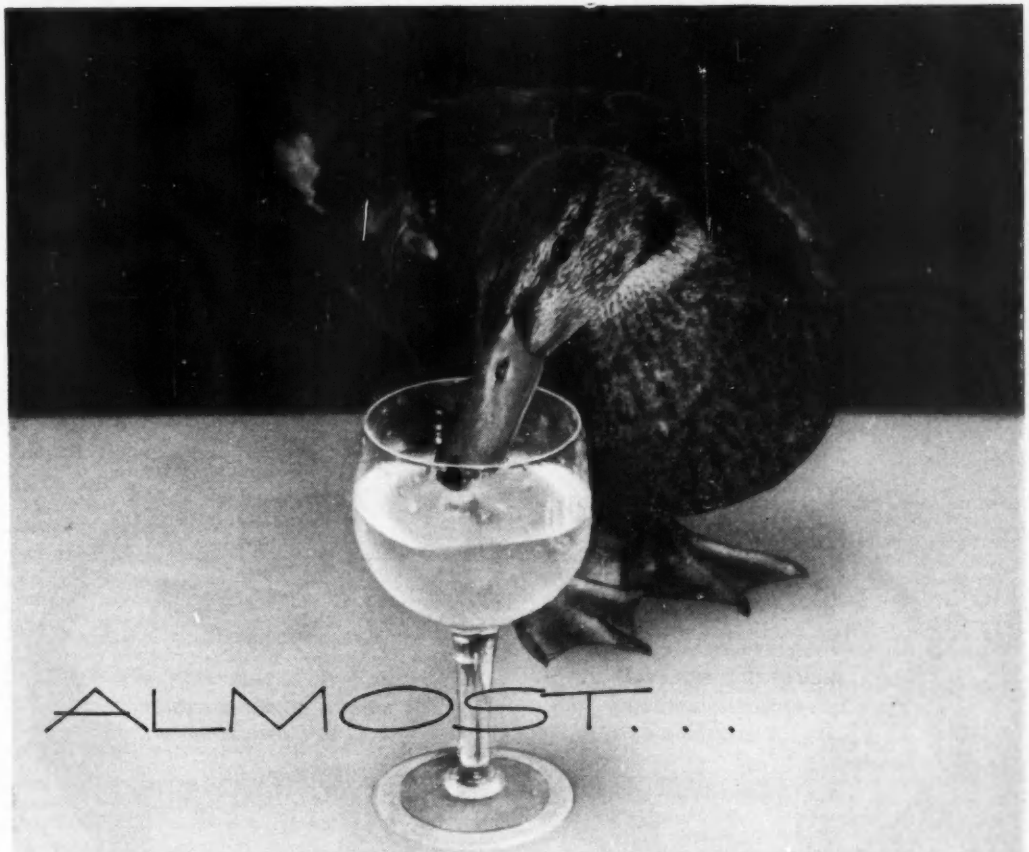

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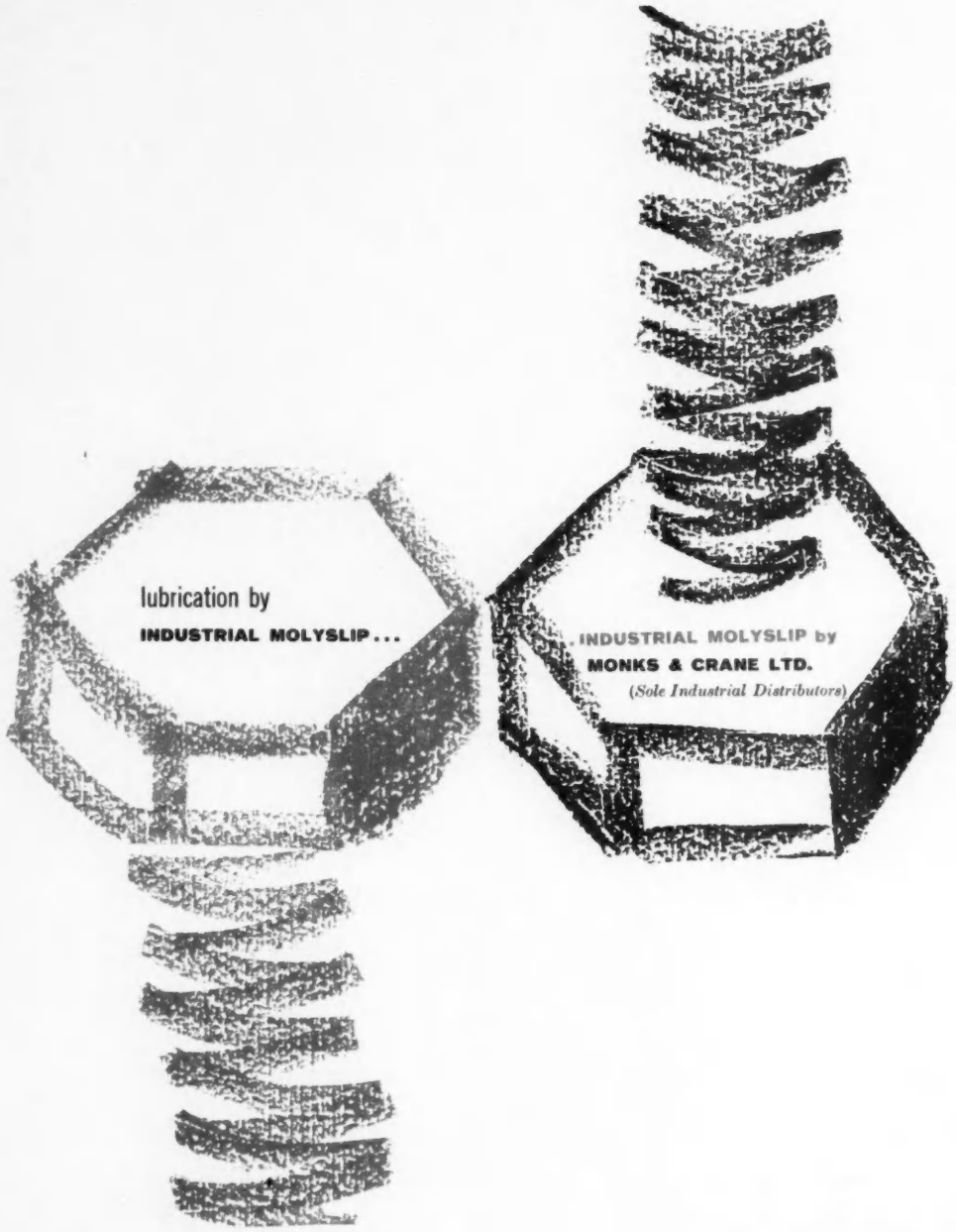

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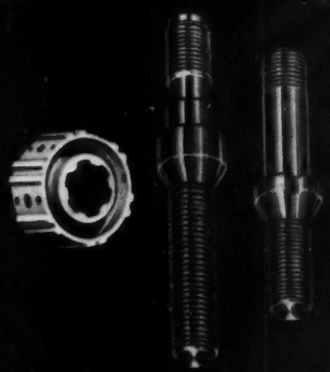

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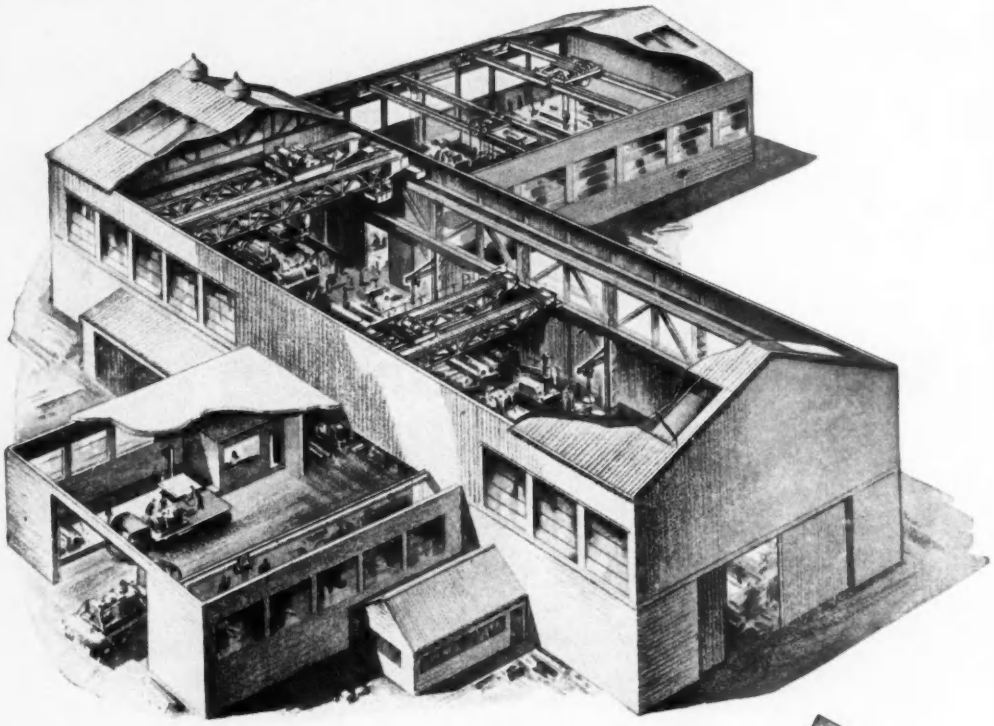

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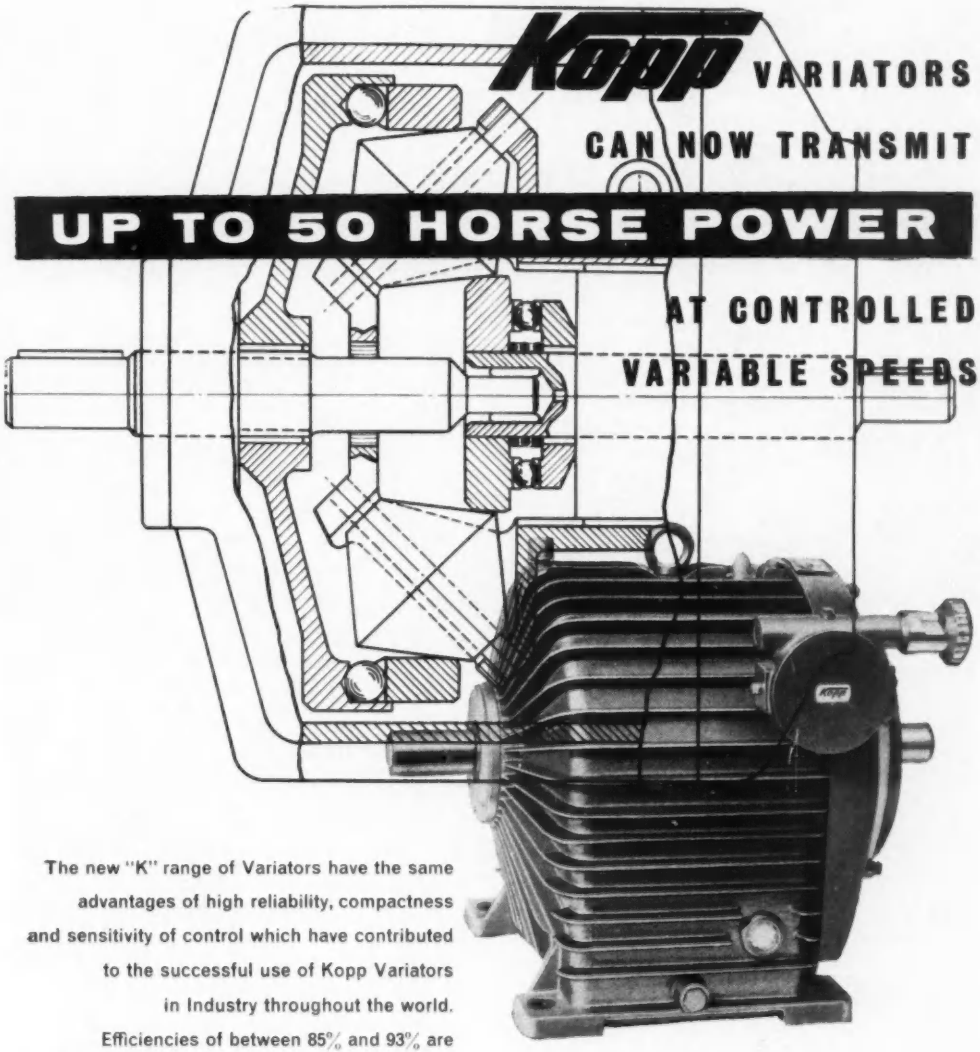

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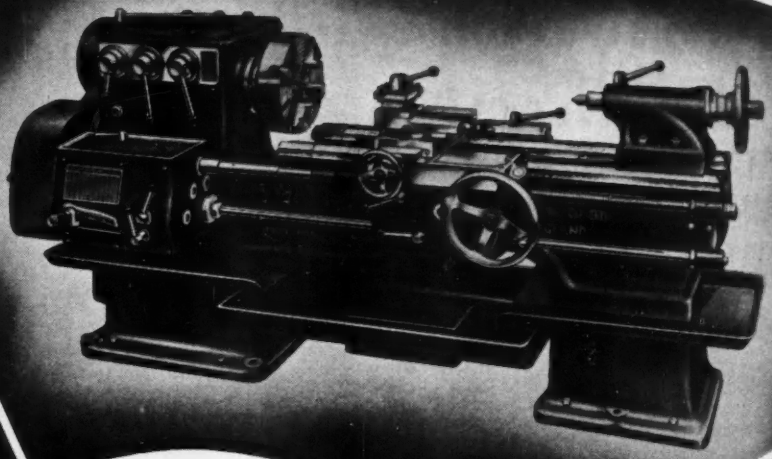

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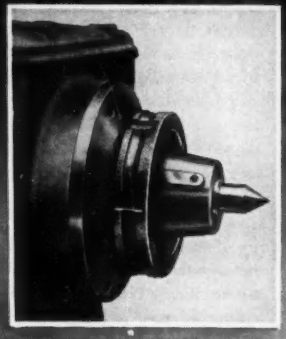

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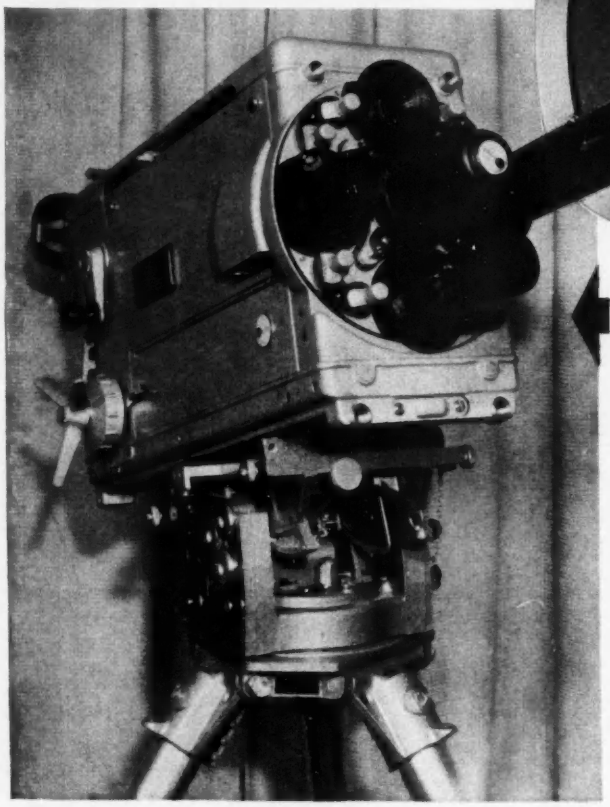

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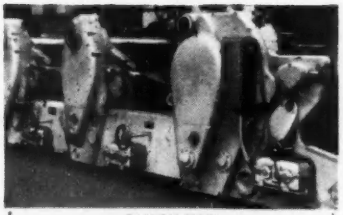

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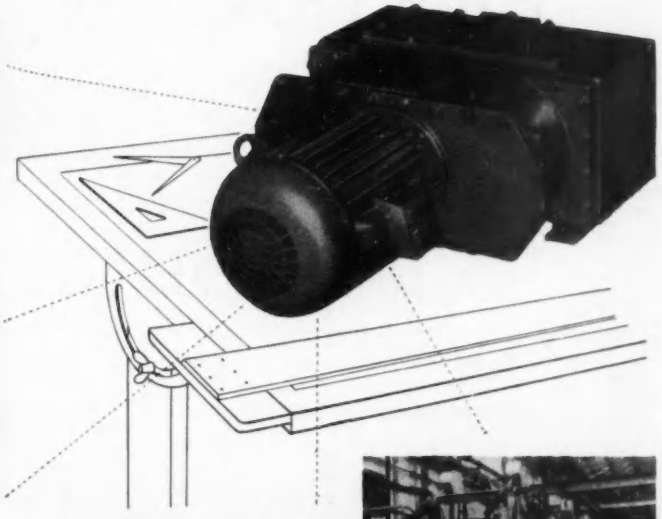
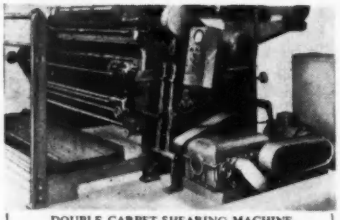
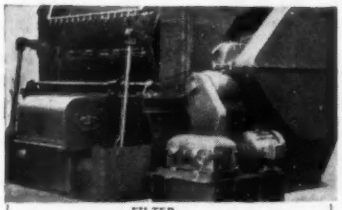




DOUBLE CARPET SHEARING MACHINE
Courtesy William Whitely & Sons Ltd.



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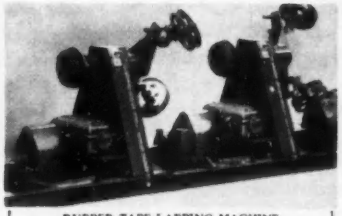
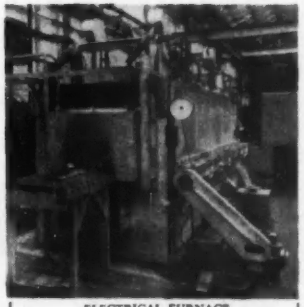
Courtesy Davey Paxman & Co. Ltd.



RUBBER TAPE LAPPING MACHINE
Courtesy B. & F. Carter & Co. Ltd.



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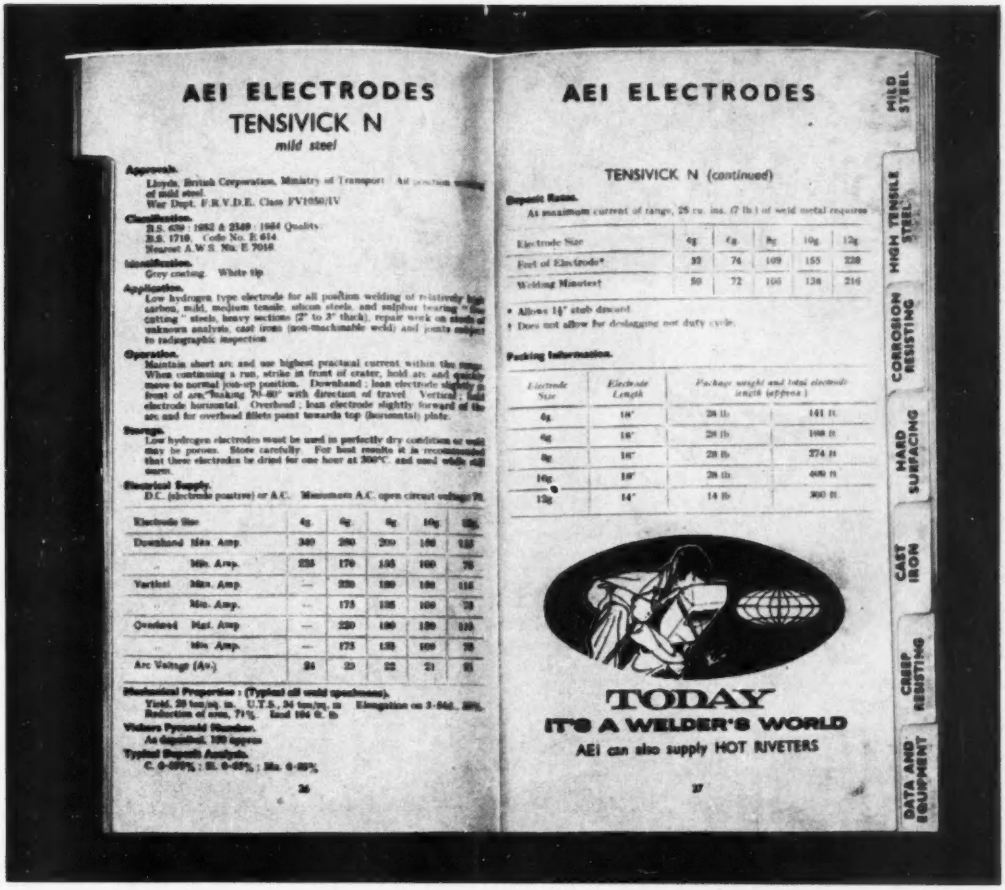

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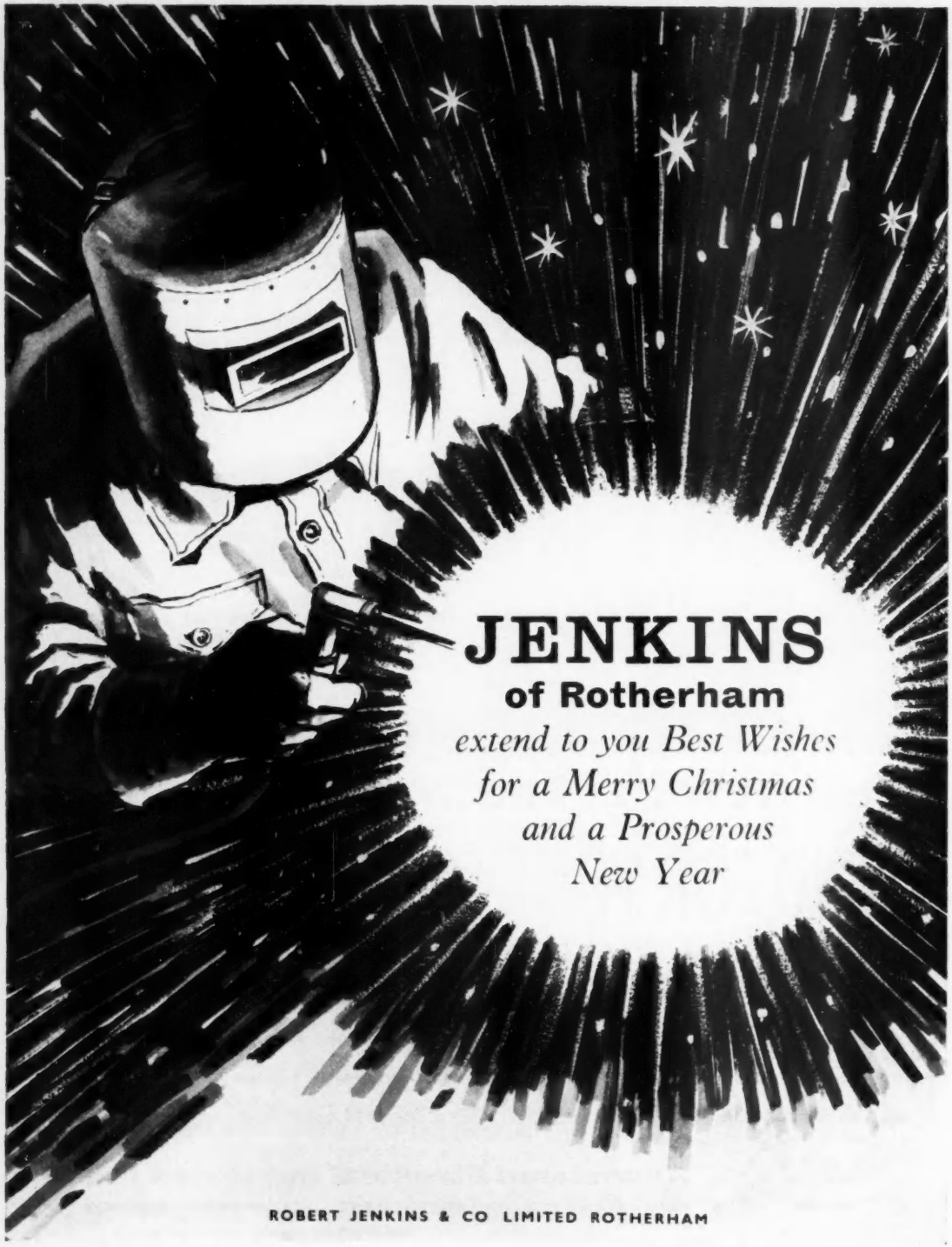
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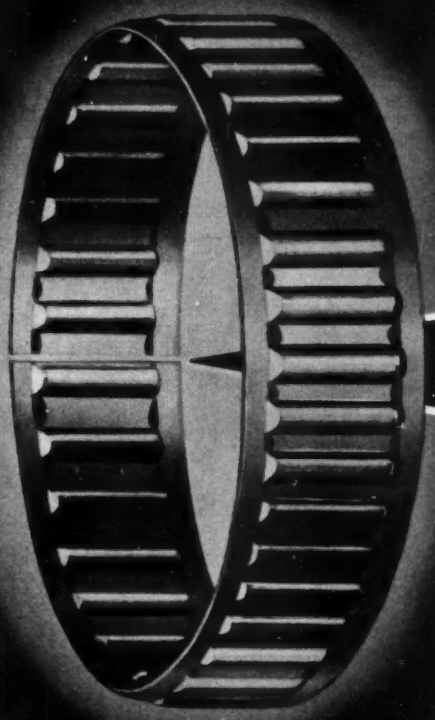

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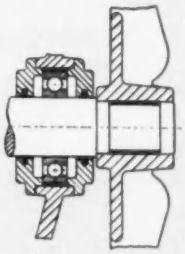
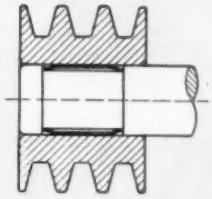


Tolerance Ring Fittings for positive power transmission in axial or rotary directions.



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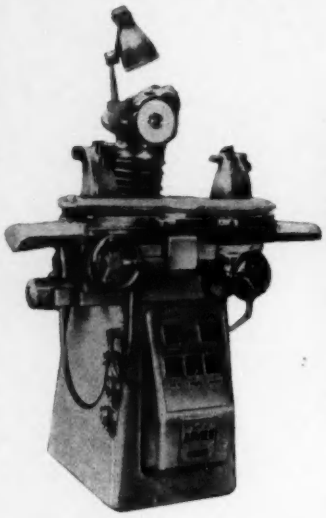

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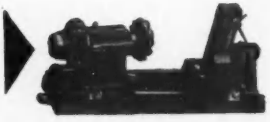

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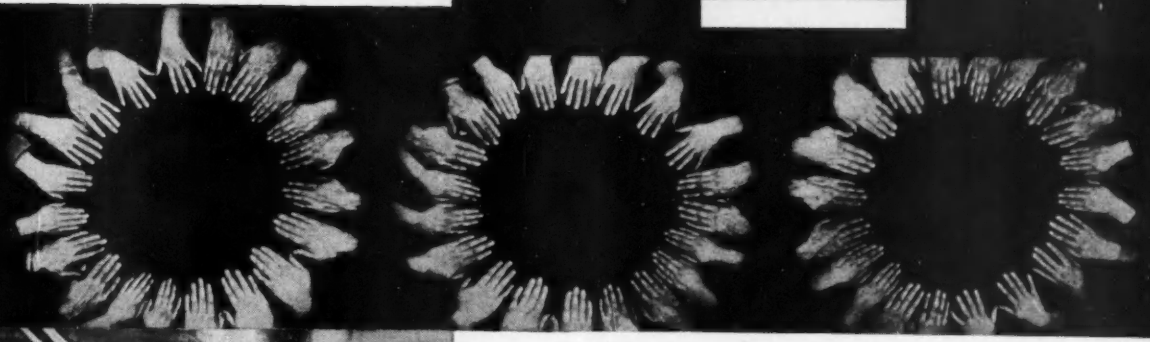

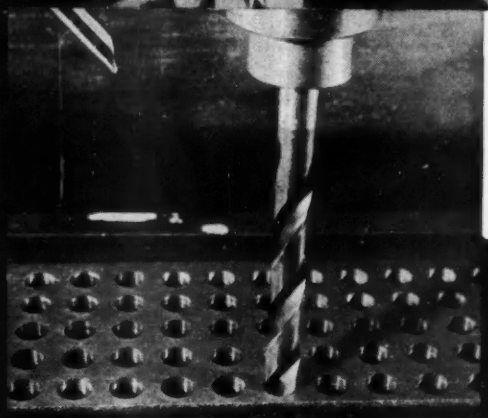

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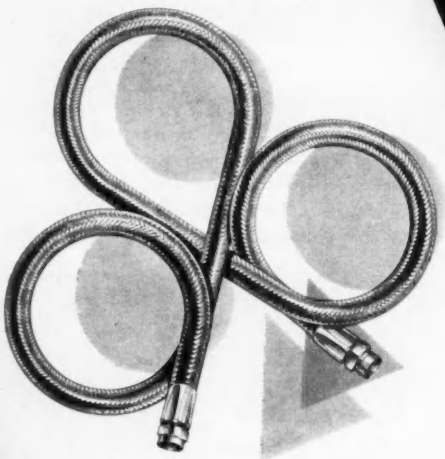

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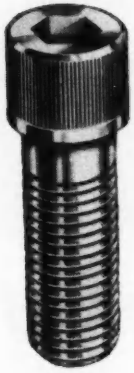

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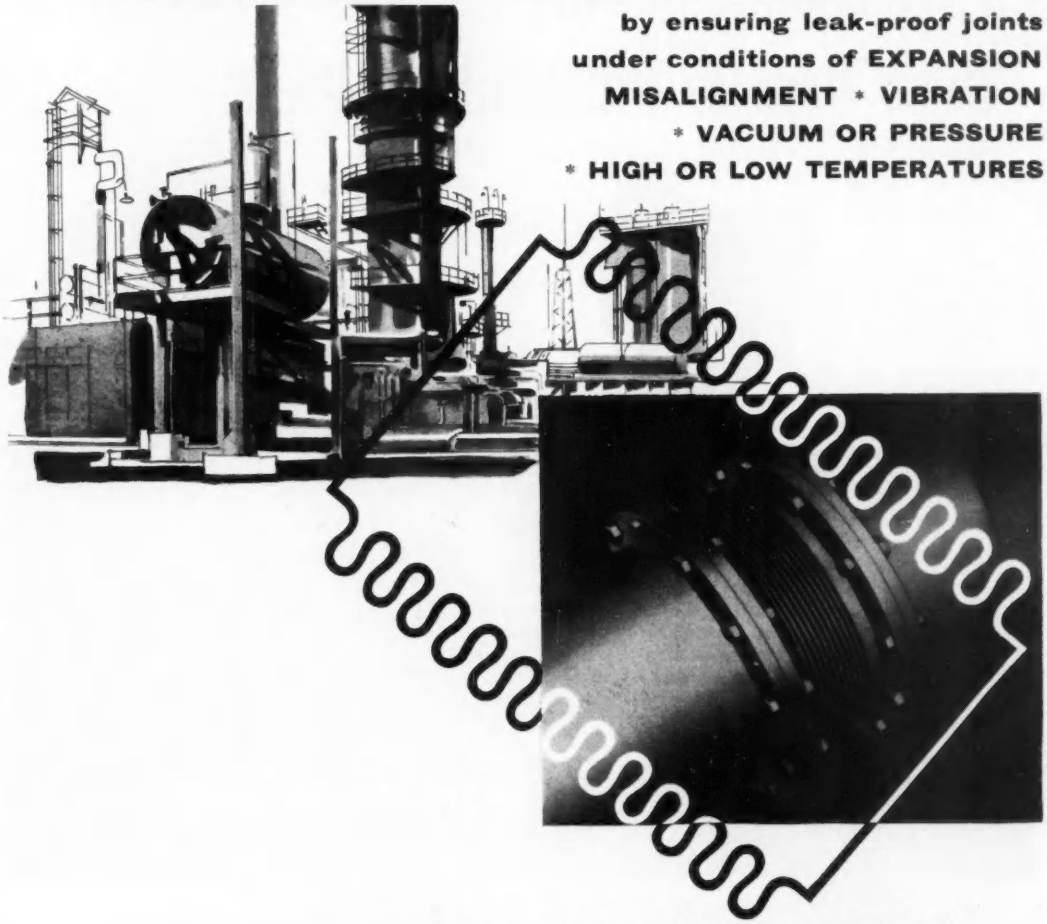

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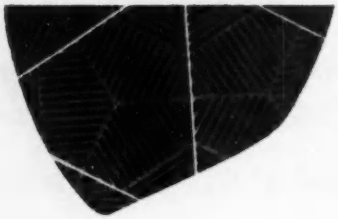

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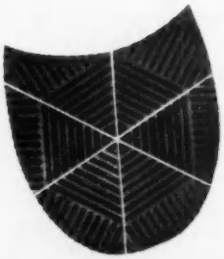

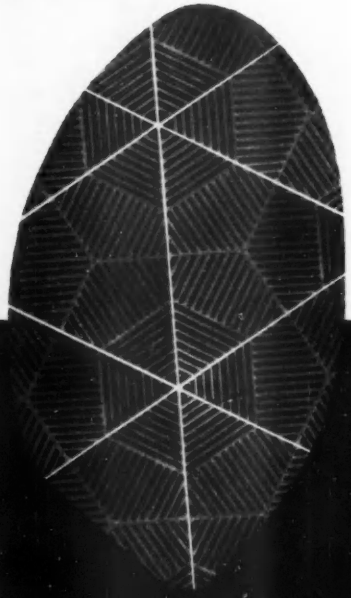

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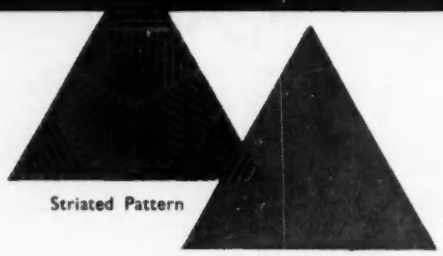

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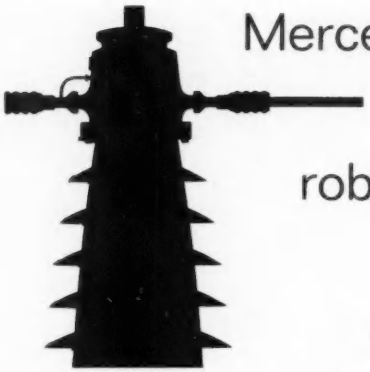

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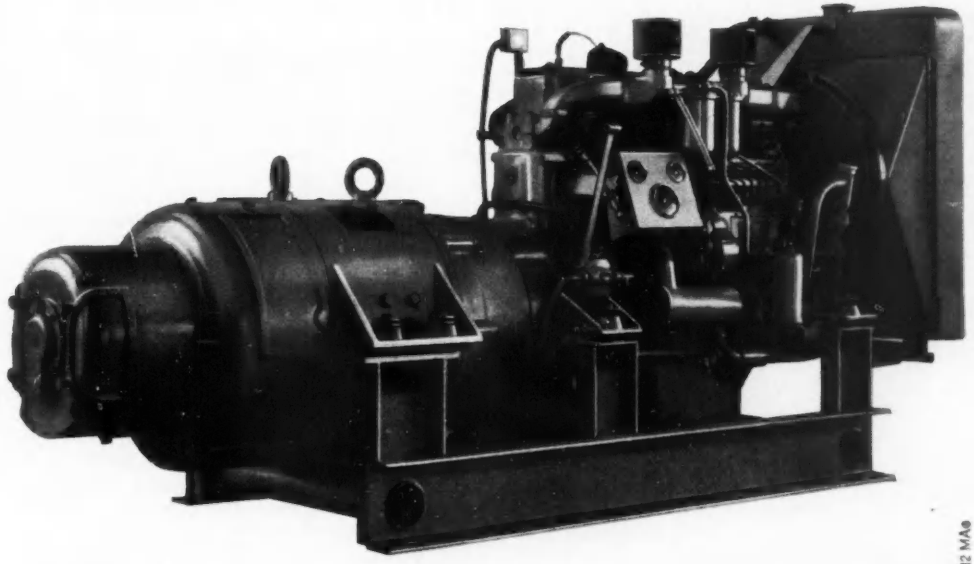

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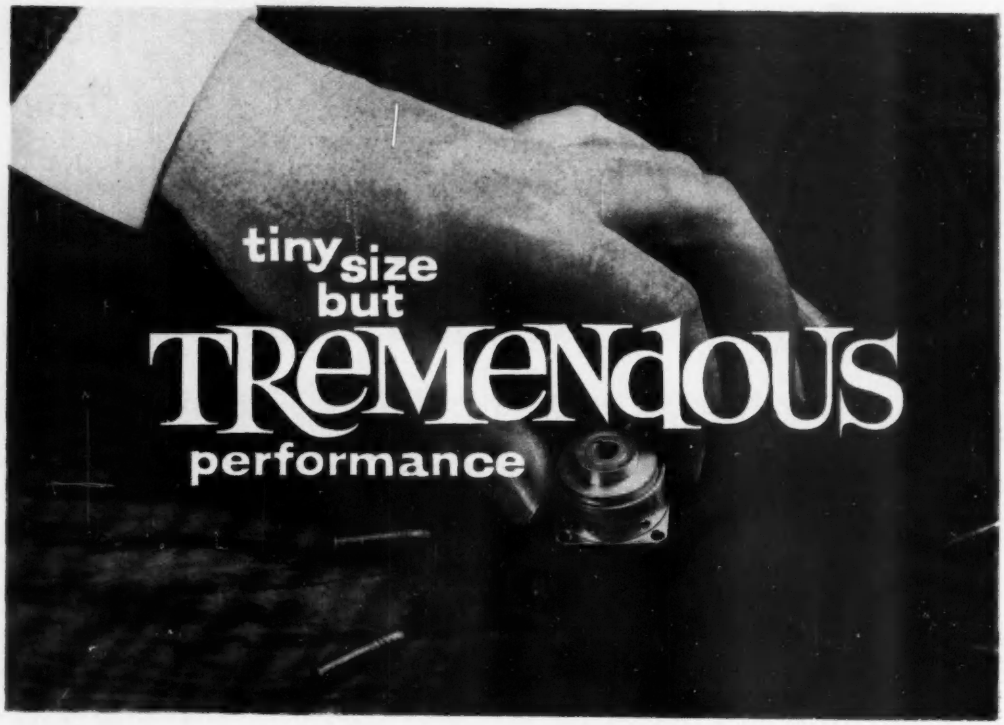

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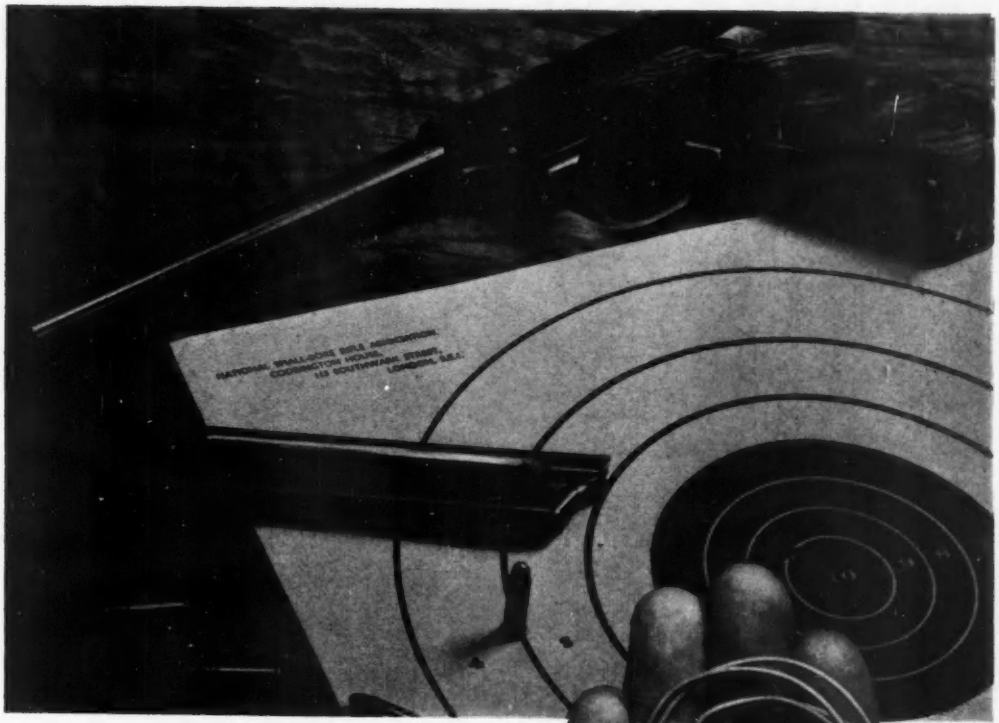

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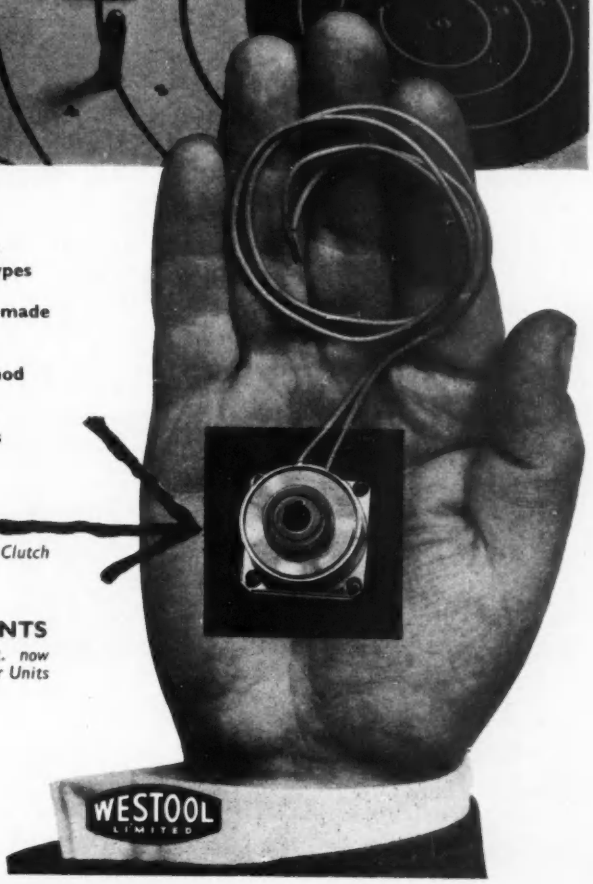

Warner SF 100 Electro-Magnetic Clutch

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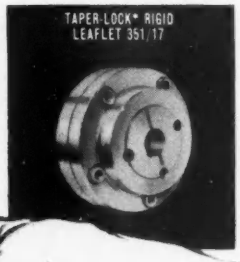

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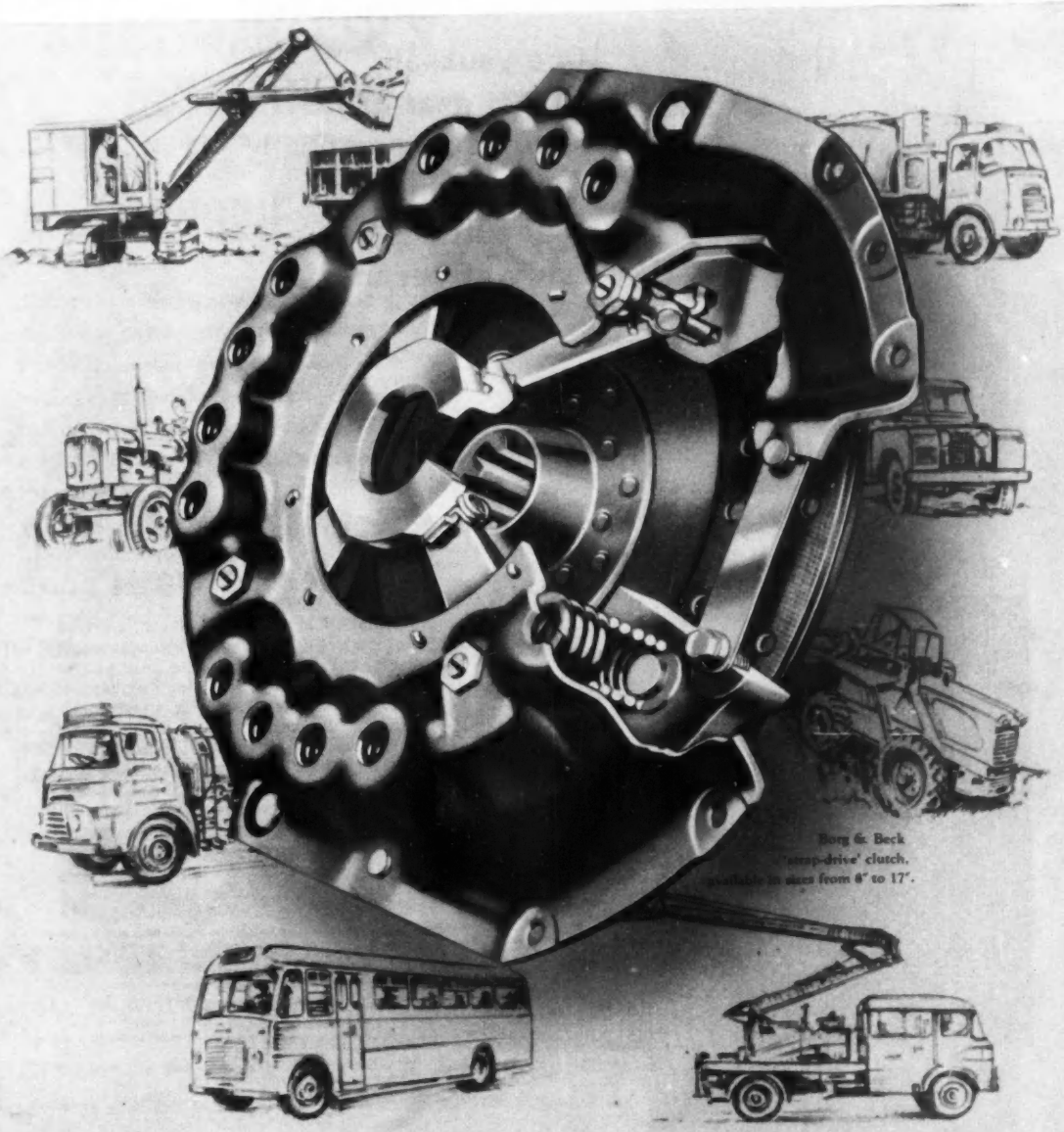

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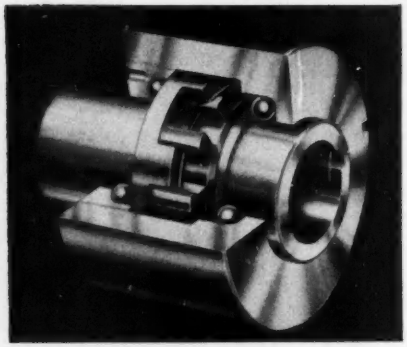

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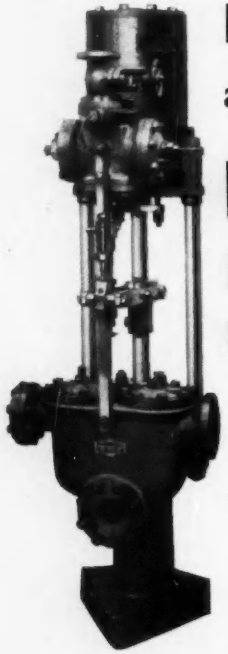

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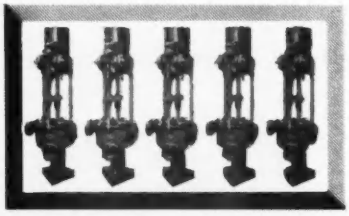

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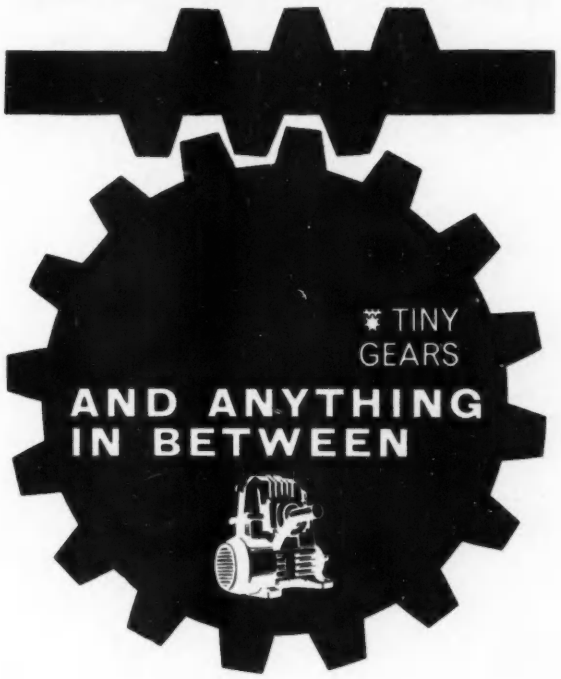

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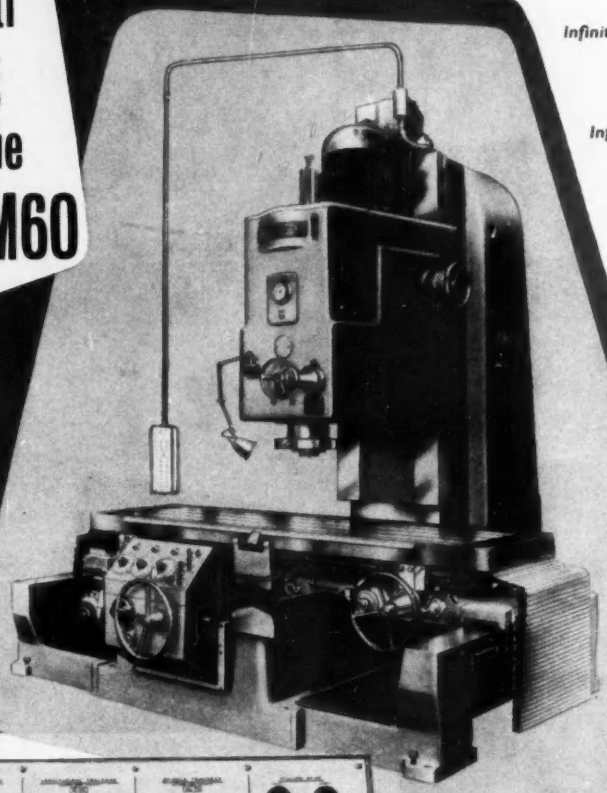

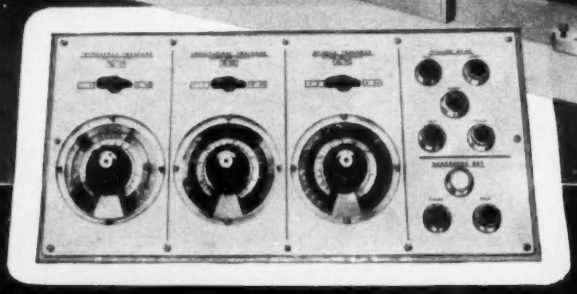

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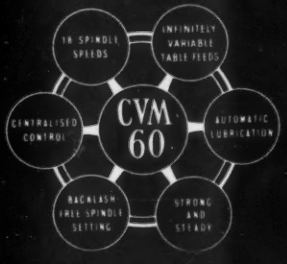

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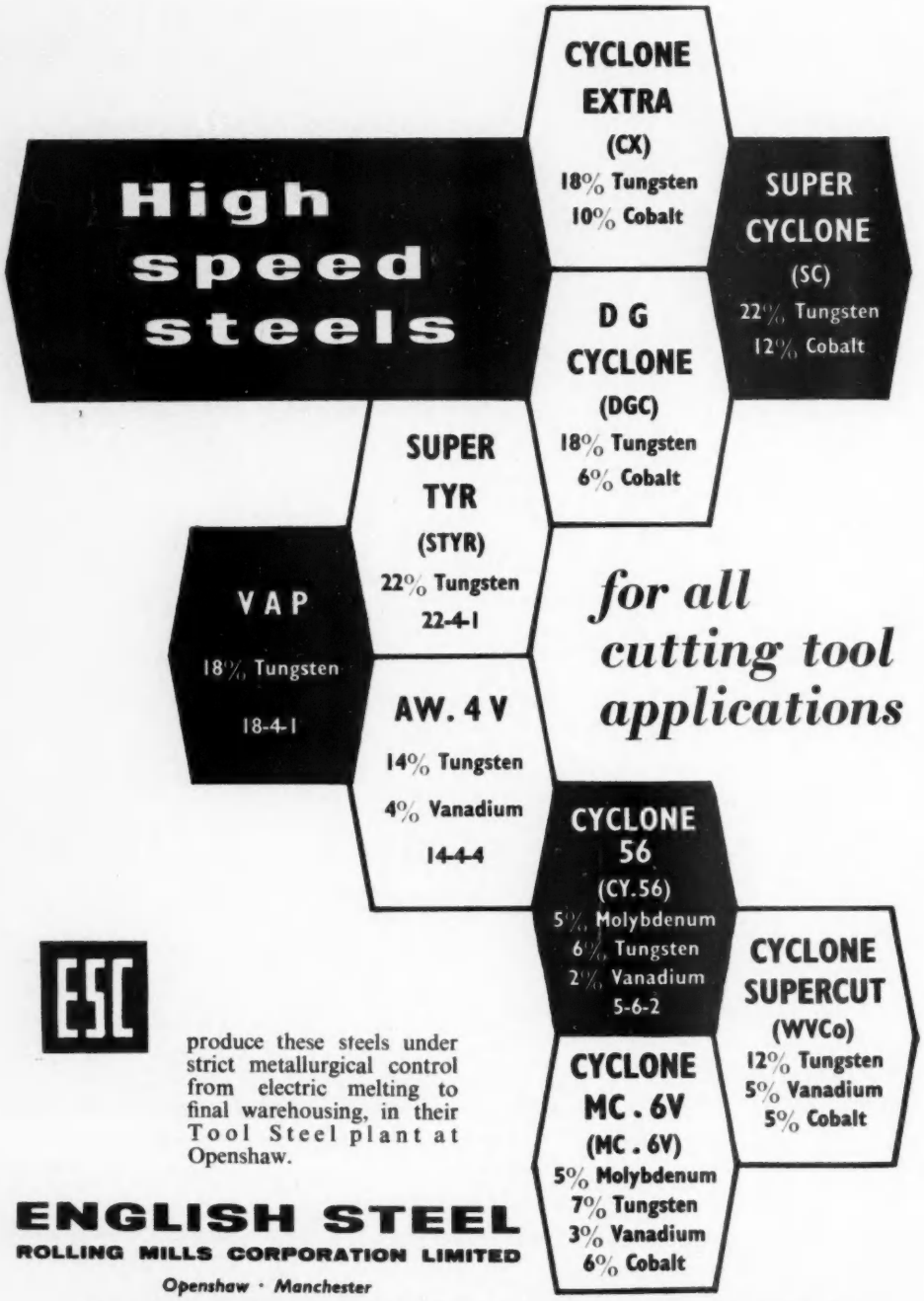
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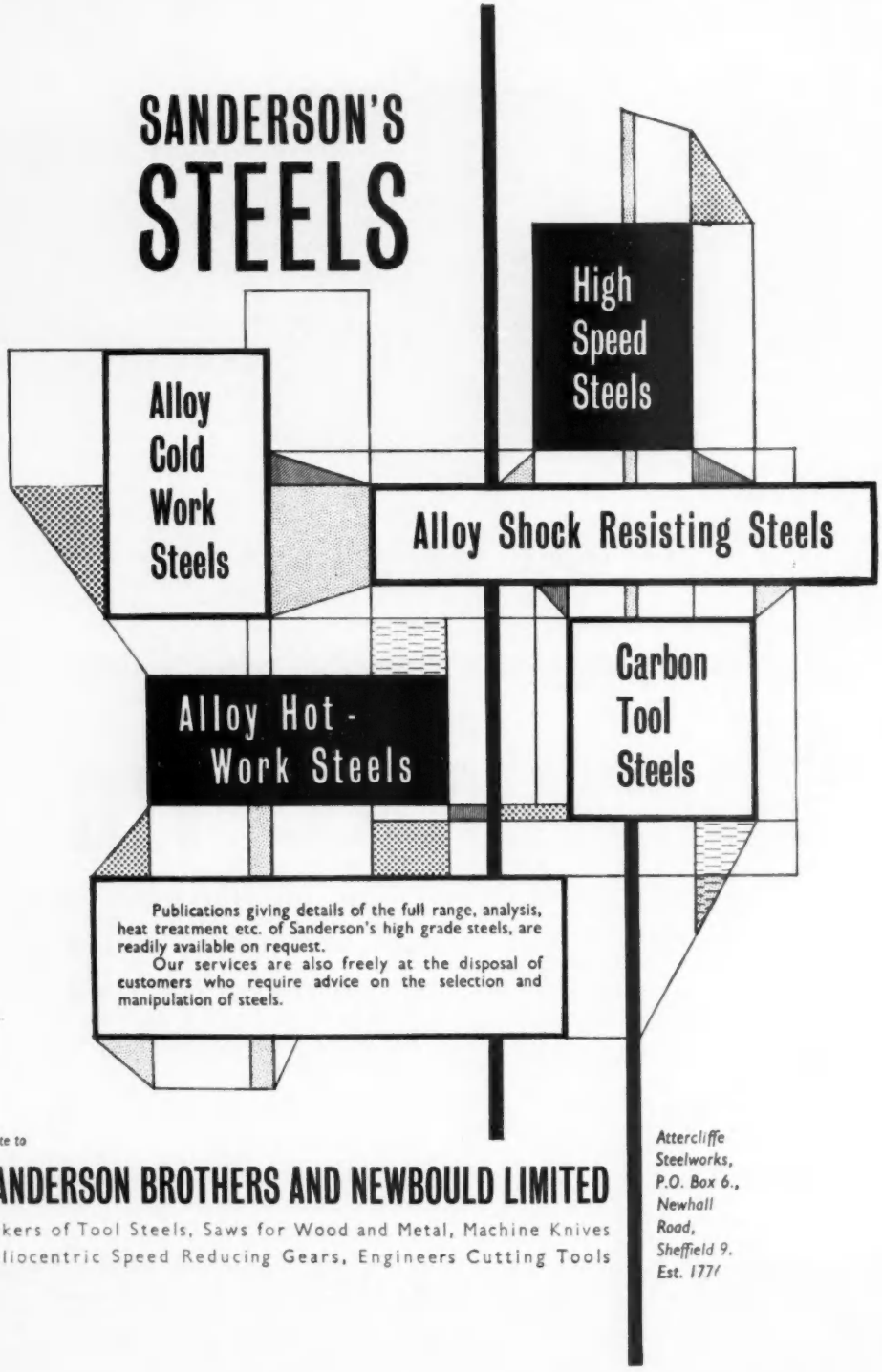
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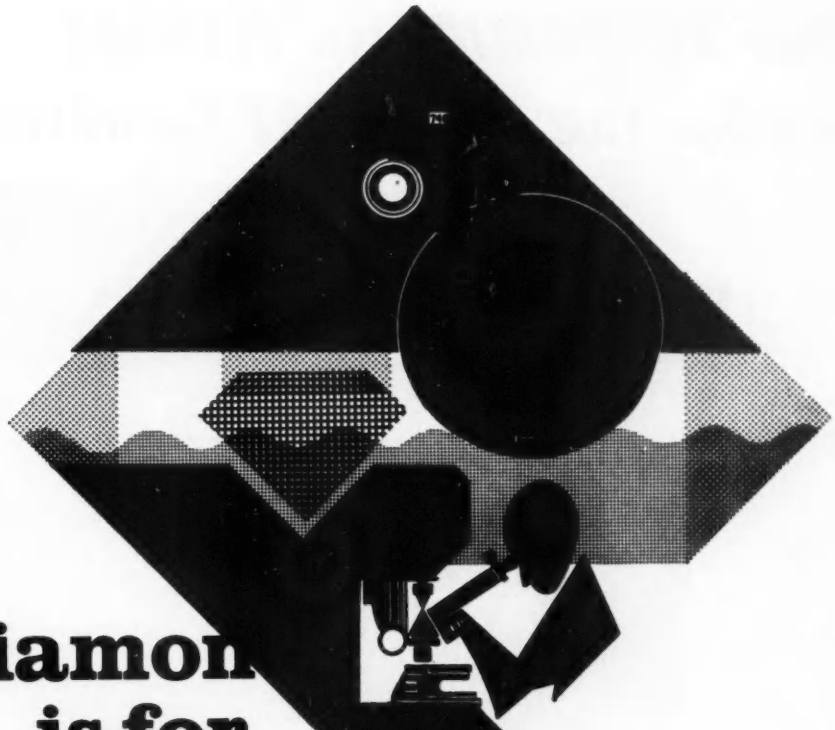

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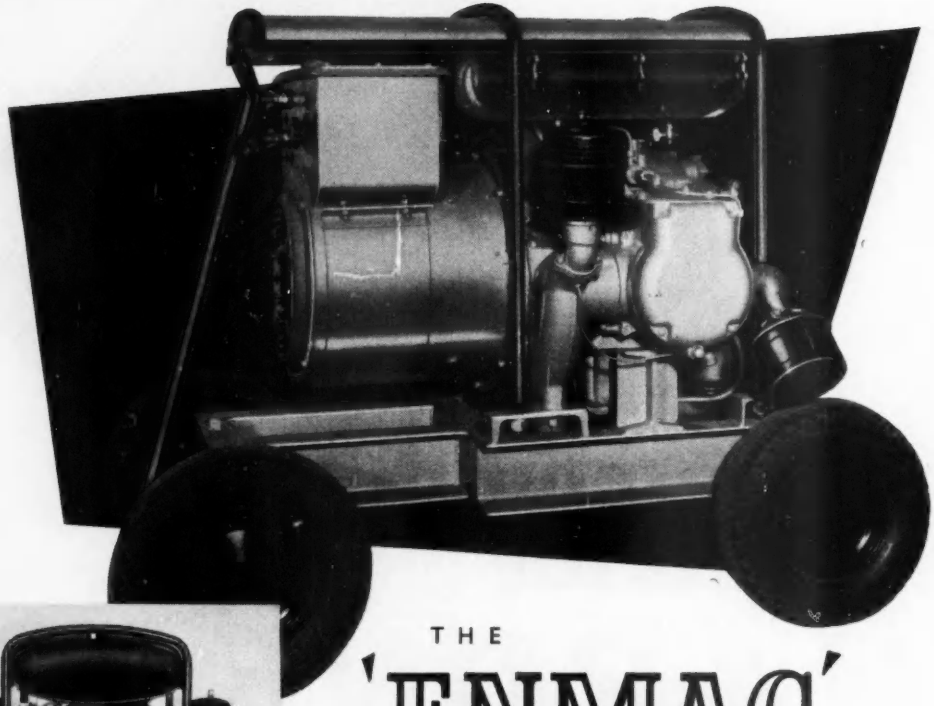

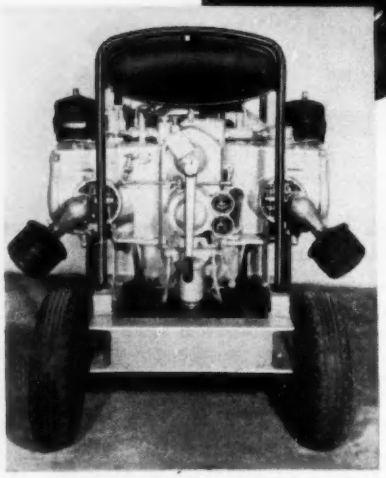

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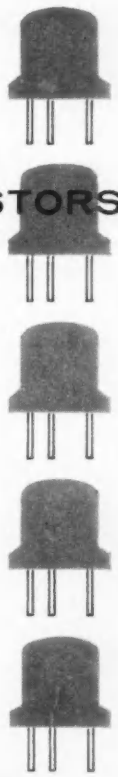

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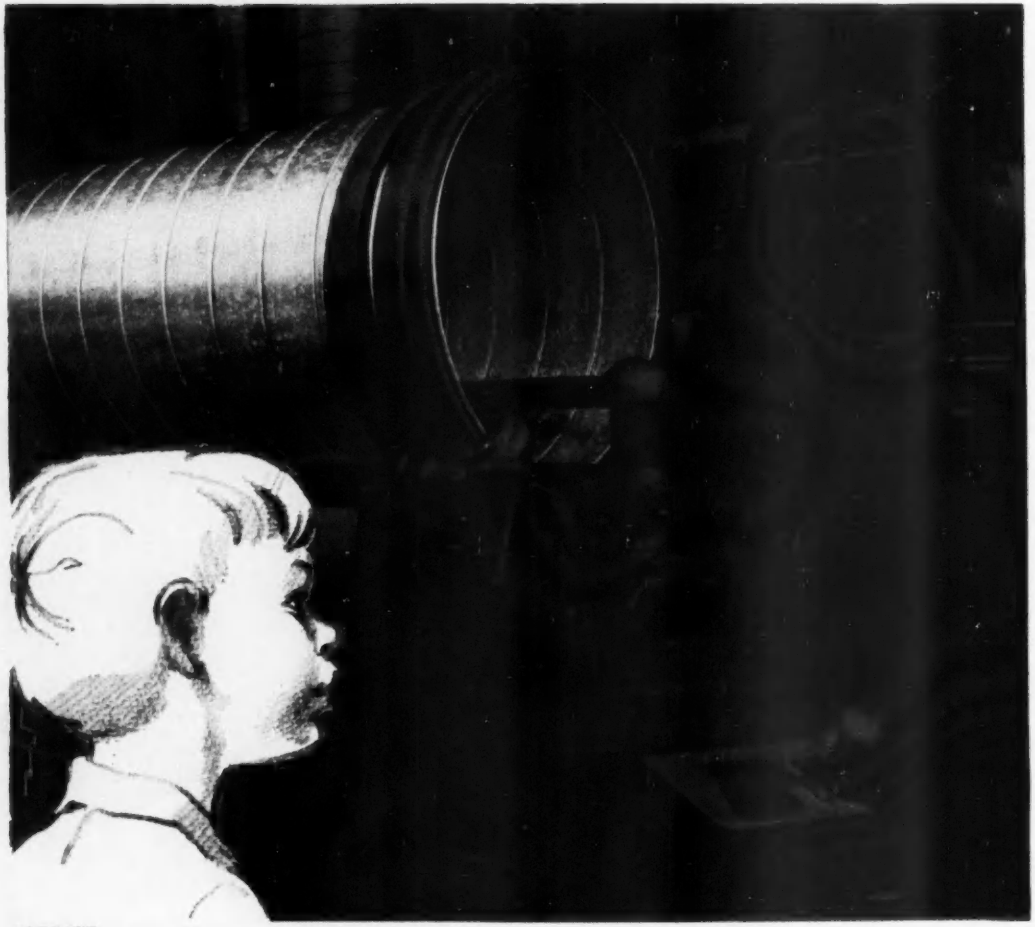

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The coating is supplied in powder form and, after mixing with water, can be applied like paint by conventional brushing, spraying, or dipping techniques. In heavy consistencies, it can also be applied by trowelling to plaster surfaces and to fill in gaps and cracks. Unlike most fire-retardant paints, the coating is not inflammable in its liquid form. Protection is afforded immediately after application, but optimum results are obtained if the coating is allowed to dry. Drying time varies with ambient temperature and the amount of water used, a typical drying time being about 1 hr for a water/powder ratio of 1:4.

From *Materials in Design Engineering*, U.S.A., October 1961, pp. 17 & 151.

● *IMPROVED EARTH-ELECTRODE SYSTEM*

Conventional earth-electrode systems, as commonly used in electrical installations for operational or safety reasons, consist of metal electrodes buried in the ground and in as good a contact with it as possible. The resistance of the earth electrode is a function of its shape and dimensions, which are usually limited by practical considerations, and of the resistivity of the ground. In many cases, the resistivity of the ground is excessively high, and it is normal practice in such cases to impregnate the soil with electrolytes such as sodium chloride to reduce resistivity. Unfortunately, such electrolytes have the disadvantage that they are not retained by the absorbent power of the soil and are entrained by seepage water, rendering frequent repetition of the treatment necessary; in addition, the presence of sodium chloride increases corrosion phenomena in metals and in concrete, while its noxious action on vegetation prevents its use on cultivated land.

These disadvantages have now been overcome by a recently patented system, in which the earth electrode is buried in soil containing from 4 to 8 kg/m^2 of calcium sulphate in its natural form as gypsum or as plaster of Paris. Because of its low degree of solubility in water, it is estimated that this concentration should be sufficient to provide an effective treatment for from 10 to 20 years. Although calcium sulphate is only slightly soluble in water, it is nevertheless an adequate conductor of electricity and, even in very dilute solutions, reduces the resistivity of the soil by a considerable extent. If desired, other substances can be added to the calcium sulphate, e.g., alkaline chlorides and nitrates to increase its solubility and also its conductivity, or certain calcium salts and alkaline sulphates to reduce its solubility. Similarly, the pH-value of the soil can be modified to facilitate the release of salts improving conductivity, e.g., by the addition of limestone in acid soils, or sulphur in alkaline soils. An important advantage of the new system, apart from eliminating the need for frequent repetition of treatment, is the fact that the substances used are not corrosive and do not harm vegetation; on the contrary, they have a favourable effect.

From *Brit. Pat. Spec.* 880,436.
C. P. Ledoux, Tarbes, France.

● *GUILLOTINES WITH VIBRATING BLADES*

Conventional guillotines for stacks of paper sheets, wood veneers, plastics, fibre-board, etc., generally use a blade to shear the material transversely, the downward thrust being accompanied by a relatively long transverse travel or slicing motion of the blade. For example, for cutting a 6-in. stack of paper, the machine is

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constructed to displace the cutting blade about 12 in., requiring a correspondingly wide machine and a costly transversing mechanism.

To overcome this drawback, a new design of guillotine has been developed, in which the knife blade is suspended from its support by leaf-springs that are stiff in the vertical direction and resilient in the horizontal direction. A mechanical oscillation generator, preferably an electric motor with an eccentric element, is coupled to the blade in such a way that it vibrates while effecting the cutting action. For some applications, especially in the case of smaller units, vibratory crystals or transducers can be used to impart the vibratory motion to the blade. In the case of a typical motor-driven oscillation generator, the weight of the blade and generator may range from a total of 20 to 100 lb, with a vibration frequency of from 50 to 1000 cps, i.e., preferably at or reasonably close to the mechanical resonant frequency of the resiliently suspended blade system. The oscillation amplitude need be no higher than $\frac{1}{8}$ in., though greater or smaller amplitudes are feasible, if required. To minimize vibrations of the knife support or other parts of the machine, induced by the vibrations of the knife, a resonant vibration-absorber arrangement is included in the design.

From *Brit. Pat. Spec.* 882,764.
Miehle-Goss-Dexter, Inc., New York, U.S.A.

● ***METHOD OF CONTROLLING THE RATE OF COOLING WHEN QUENCHING METALS***

When quenching metals for the purpose of modifying such physical characteristics as hardness, tensile strength, and ductility, the rate of cooling obtained with water as the quenching medium is in some cases excessive and may result in the formation of quench cracks. It is true that slower rates of cooling can be obtained by quenching in oil, but in some cases it can occur that these rates are too slow to achieve the desired modifications of the physical characteristics of the metal. It would therefore appear that there is a definite requirement for a quenching medium providing cooling rates intermediate between those normally obtained by the use of water and those obtained by the use of quenching oils.

It is now reported that such a quenching medium has been developed and that it enables a controlled rate of cooling to be achieved. Essentially, the medium comprises an aqueous solution of sodium alginate, which serves to reduce the peak rate of heat extraction from the metal. Control of the rate of cooling is effected simply by varying the concentration of sodium alginate in the solution, normally from 0·1 to 0·5% by weight. Thus, for quenching plain carbon and alloy steels, a solution containing not more than 0·5% by weight of sodium alginate provides the desired cooling conditions for successful quenching from temperatures in the range between 700 and 1000°C. A small amount (about 0·05% by weight) of sodium metaphosphate is normally added to the quenching solution to prevent the formation of calcium alginate, caused by the presence of calcium in hard water. This addition is not required when softened water is used.

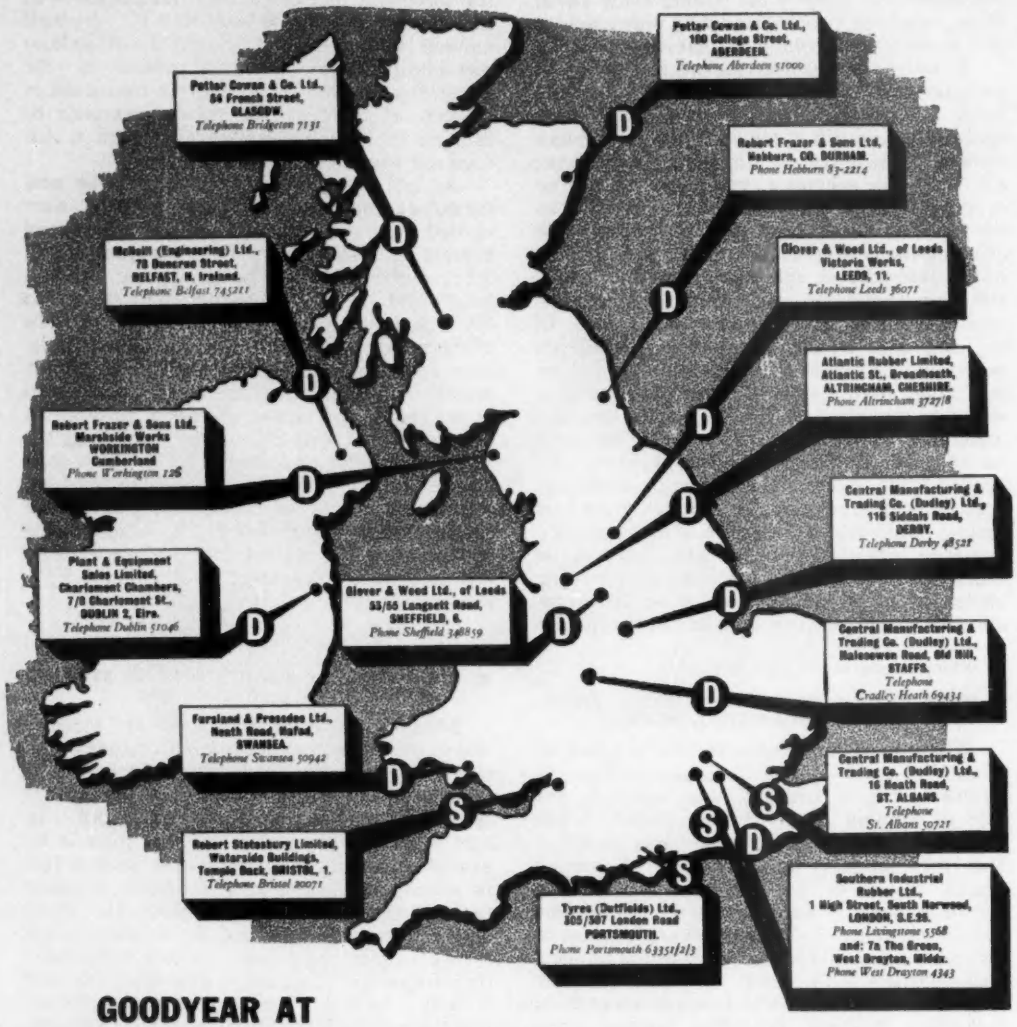
As an example of the effect of the new quenching medium, comparative tests were carried out on specimens of an alloy steel containing 0·3% carbon, 1·5% manganese, and 0·3% molybdenum. The specimens, 5 in. in length and 1·5 in. in diameter, were heated to 850°C and then quenched vertically in 15 gallons of the medium, initially at 23°C. Subsequently, each specimen was divided transversely in the middle, and hardness measurements were taken at the centre and at the cylindrical surface. It was found that, with plain water quenching, the surface hardness was about 12·7% higher than at the centre. With a quenching medium containing 0·2% of sodium alginate, the corresponding value was 9·2%, while media containing 0·3% and 0·4% of sodium alginate further reduced this value to 5·4% and 5·2% respectively.

From *Brit. Pat. Spec.* 880,445.
G.K.N. Group Services Ltd., Smethwick, England.

● ***METHOD OF HANDLING GASES BY STORING IN ICE***

Many gases commonly used in industry and in the laboratory are normally handled and transported by storage in thick-shelled containers under pressure, requiring the use of specialized and often costly techniques. In fact, it is generally recognized that there is no available method of handling such gases at low or atmospheric pressure, at moderate temperatures, and in thin-walled containers. Even carbon dioxide, which can be handled in the form of dry ice, requires the use of well-insulated or refrigerated containers; otherwise, the cost is likely to be high. It is now reported, however, that these difficulties have been largely overcome by a new technique which makes it possible to store large volumes of gas in a form suitable for handling at atmospheric pressure.

Essentially, the process involves the production of what may be called "gasified ice", comprising a solid matrix of ice containing the gas. The freezing point of the product ranges between 0°C and a maximum of 14°C and can be maintained for extended periods at atmospheric pressure, while the gas can be liberated from the product as desired. Typical gases that can be stored in this way include carbon dioxide, carbon monoxide, nitrous oxide, hydrogen sulphide, methyl chloride, chlorine, helium, neon, argon, and krypton. The process is carried out in a reaction vessel by absorbing the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gas in agitated tap water, the gas pressure being maintained at between 150 and 600 psig and the temperature between 0 and 14°C. The reaction time is controlled to give the desired amount of gas in the product, ranging, for instance, from about 50 to 90 millilitres per gram of ice for carbon dioxide to from 40 to 55 millilitres per gram of ice for nitrous oxide. At the end of the desired time, the frozen product is removed from the reaction vessel and is in most cases ready for immediate use. The resulting ice resembles ordinary cloudy or clear ice and is free of liquid. Its freezing point is most commonly between 4 and 8°C, and it has the characteristic of being able to release the gas at a controlled rate when melted, e.g., by adding it to water.

An interesting sideline is that, in the case of carbon dioxide, the product can be used for making carbonated drinks. For instance, if a piece of this ice of roughly the same size as a conventional ice cube is dropped into about half a pint of water, a vigorous evolution of carbon dioxide is observed, giving a resulting beverage which closely resembles ordinary soda water. Furthermore, the carbonated ice cube lasts for about the same time as an ordinary ice cube in water. If stored in a refrigerator at −10°C, no loss of gas is apparent for extended periods, e.g., more than one month.

From *Brit. Pat. Spec.* 882,886.
General Foods Corporation, White Plains, N.Y., U.S.A.

● ***PHOTO-ELECTRIC PYROMETER***

Temperature determinations made with an optical pyrometer not only depend on the sensitivity of the human eye to differences in brightness and on a knowledge of the mean effective wavelength of the radiation being viewed, but also involve possible psychological factors in judgment. To overcome these disadvantages, a new pyrometer which utilizes a photo-electric system rather than the human eye for detecting matching radiance has been developed. Tests with this pyrometer have shown that, at a temperature of 1063°C, it has an accuracy of 0·02°C, as compared with 0·3°C for a good visual optical pyrometer at the same temperature.

The optical system of the photo-electric pyrometer differs from that of a conventional pyrometer in that images of both the source and the pyrometer lamp are focused in a plane containing a slit, rather than in the focal plane of an ocular. The surface containing the slit is highly polished, so that a reflected image is available for visual alignment of the pyrometer. Radiation passing through the slit falls on a photo-multiplier tube, the amplified output from which is recorded on a strip chart. The images of the source and the pyrometer lamp are alternately positioned on the slit, and the response of the photo-tube, as seen on the strip chart, guides the operator in making adjustments of the pyrometer-lamp current. A multi-element filter in the optical system isolates a band of wavelengths at 6530 Å, with a half-width of about 110 Å. This bandwidth is about one-fifth of that used in visual optical pyrometry and should permit determination of the mean effective wavelength with greater accuracy. Three pyrometer lamps are incorporated in the instrument, and these can be interchanged for making radiance matches. In this connection, it should be noted that, despite extensive heat treatment of the lamps prior to use, unexpected gradual changes up to 0·5°C in 150 hr of operation have been detected. For this reason, work is being directed to improve the long-term stability of these lamps.

From *NBS Technical Bulletin*, U.S.A., October 1961, p. 165.

● ***CRYOGENIC STRETCHING OF METALS TO IMPROVE STRENGTH***

Basically involving welding a cylinder, pressure vessel, etc., cooling it with liquid nitrogen, and then expanding it by the application of internal pressure, a new metal-working process, known as cryogenic stretching, is stated to confer a considerable increase in the strength and ductility of many welded shapes and to reduce the cost of fabricating stainless steel to less than that of fabricating and heat-treating low-alloy steel. For example, vessels fabricated from Type 301 stainless steel have been stretched 13% by means of this technique, resulting in an increase in tensile strength of 158,000 psi, i.e., from 102,000 to 260,000 psi, with a yield-strength value approaching 240,000 psi. With suitable design and material selection, it is claimed that units stretched in this way could have nominal tensile strengths in the range of 400,000 psi. So far, most research work on the new process has been done on Type 301 stainless steel, though some experiments have been carried out with Types 302 and 304 stainless steels. It would appear that the process is best suited to Type 301 steel, because this material achieves maximum strength with minimum working. Other experiments are being performed with aluminium and titanium, and the preliminary results seem promising.

The major difference between the new process and other sub-zero forming processes is that welding is effected first. In the other techniques, much of the improvement in tensile strength and ductility is lost when the worked material is welded, whereas both the welds and the base metal are work-strengthened at cryogenic temperatures in the new process. In applying the process to the fabrication of, say, a pressure vessel, the first step is to make an undersized

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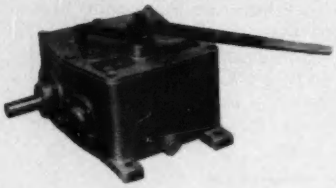

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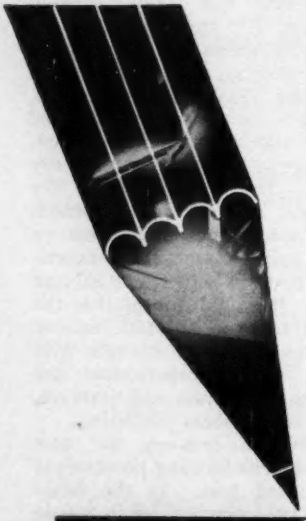

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vessel. The vessel is then placed inside a forming die in a forming tank, and both the tank and vessel are filled with liquid nitrogen, the vessel being sealed, except for a pressurizing line leading to a supply of compressed nitrogen. As soon as the vessel has reached the temperature of the liquid nitrogen, the pressurizing line is opened, stretching the vessel to the die dimensions, after which the nitrogen gas is vented off and the vessel is removed for final machining. For safety, the forming tank is located out of doors in a pit which, as an additional precaution, is covered by a blast mat.

From *Machine Design*, U.S.A., September 14, 1961, pp. 40 & 42.

● ***MINIATURE ELEMENTS FOR MEASURING RELATIVE HUMIDITY***

Measuring about 0·6 × 0·2 in., with an active surface area of about 0·004 sq in., a new aluminium oxide element for measuring relative humidity in the range between 0 and 100% has been developed on an experimental basis and is stated to have proved superior in many respects to the lithium chloride elements commonly used for this purpose. Thus, condensation of moisture on the surface of the element does not permanently affect it, and it can operate satisfactorily over an extended temperature range (−80 to +165°F with proper correction curves), while its very small size and high measuring speed make it especially suitable for use in applications where these factors are important in electrical measuring or control devices. In addition, production techniques are conventional and not too costly, and the element is still operative after long periods of storage in the uncontrolled condition.

The element is constructed of two electrodes or layers of aluminium, separated by a porous coating of aluminium oxide formed by anodizing the surface of either a plate or a foil, the other aluminium electrode being deposited over the anodized coating by an evaporation process. Any change in relative humidity causes a change in impedance between the two electrodes, enabling the element, in conjunction with appropriate circuitry, to be used for indicating the value of relative humidity on a meter.

From *Mechanical Engineering*, U.S.A., November 1961, p. 74.

● ***DIRECT NICKEL-PLATING OF ZINC-ALLOY DIECASTINGS***

The established method of nickel-plating zinc-alloy diecastings involves the deposition of a primary copper coating directly on the zinc alloy and then plating the copper with nickel. This method has certain well-known disadvantages and, for this reason, various methods of plating zinc alloys directly with nickel without an intermediate copper layer have been proposed. In one of the most promising of these, a nickel sulphate solution is used, with additions of citric acid, sodium pyrophosphate, sodium bisulphite, sodium citrate, and sodium chloride, the pH-value of the bath being maintained at between 7·5 and 9·0 with ammonia. This bath seems to have good throwing power and to be free from burning, with a better toleration for zinc than plating solutions with low pH-values. However, the presence of a considerable amount of sodium in the solution is believed to cause stresses in the nickel deposit, while the presence of ammonia tends to hinder the precipitation of zinc, and the quality of the plating is likely to be adversely affected by the zinc remaining in solution.

To overcome these disadvantages, a new method of depositing nickel directly on zinc-alloy diecastings has been developed and basically involves the use of solutions of nickel citrate made alkaline with any alkaline metal hydroxide, the nickel citrate acting both as the source of nickel and as the complexing agent necessary to maintain solubility in an alkaline solution. Nickel chloride is added to improve anode corrosion, sodium citrate to help maintain solubility, and nickel (in the form of nickel carbonate) to improve the quality of the deposit. For a simple dull deposit of good appearance, the recommended proportions of reagents to be added are 148 gm/litre of citric acid, 13 gm/litre of nickel chloride, 17 gm/litre of sodium citrate, and nickel carbonate to saturation This solution is maintained at a pH-value of from 7·0 to 7·5 with sodium hydroxide, and plating is carried out at a current density of from 30 to 70 A/sq ft and a bath temperature from 55 to 65°C. A less dull deposit can be obtained if from 10 to 40 gm/litre (preferably 13 gm/litre) of nickel formate is added to these constituents, while a fully bright deposit can be obtained by the further addition of about 3 gm/litre of formaldehyde solution and between 0·2 and 1·0 gm/litre of saccharin. If desired, an original dull deposit of nickel obtained in this way can be used as a basis for the well-known duplex effect obtained by over-plating with a bright deposit from a conventional acid bath.

From *Brit. Pat. Spec.* 880,786. National Alloys Limited, London, England.

Readers desiring further information on any developments reported in THE BLUE PAGES are invited to write to the Editor. Copies of the full specifications of any British patents mentioned, which are published by courtesy of H.M. Stationery Office, should be obtained from the Patent Office, 25 Southampton Buildings, Chancery Lane, London, W.C.2. Price 4s. 6d. each.

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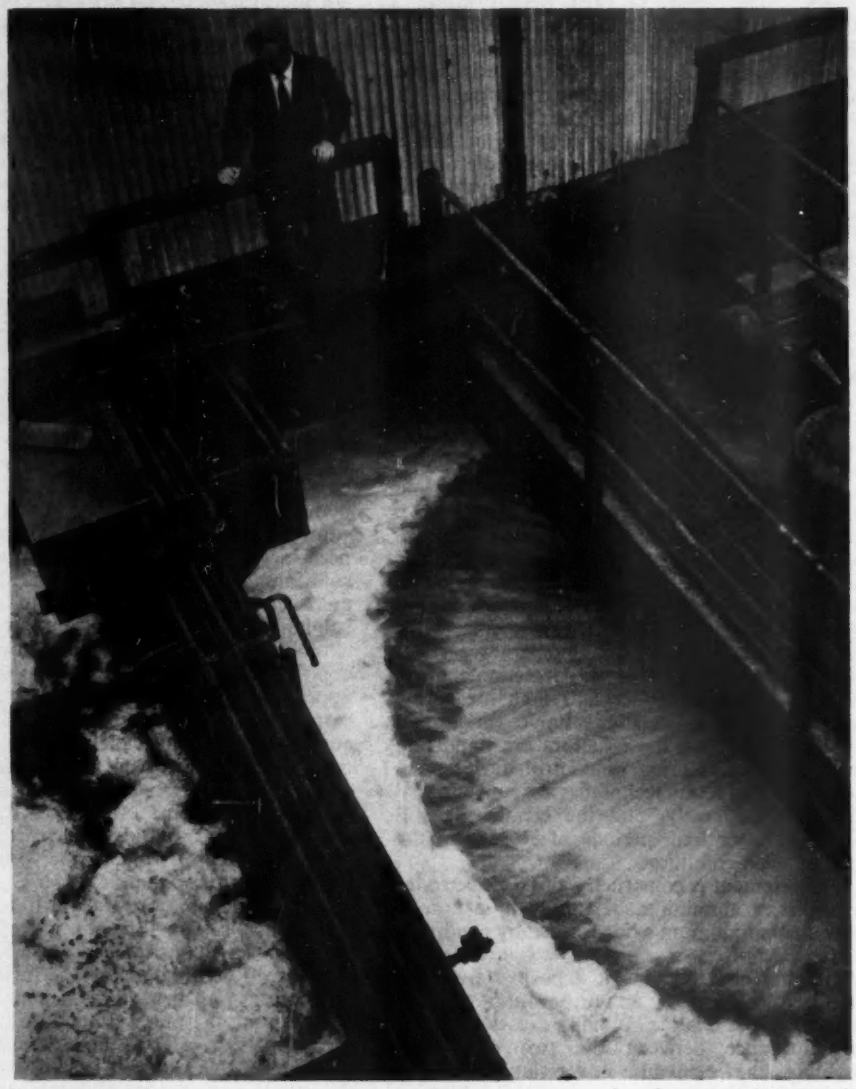

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THE ENGINEERS' DIGEST
A World review of DESIGN & PRODUCTION—RESEARCH & DEVELOPMENT
VOL. XXII No. 12 DECEMBER, 1961

Value Engineering

By P. CAHN-SPEYER*

OBSERVERS of the American industrial scene cannot have failed to note the rapidly expanding recognition of the concept of value engineering as an aid to economical manufacture. The increasing number of papers on this subject presented to engineering societies, the relatively large amount of space devoted to articles on the various aspects of value engineering in technical periodicals, and the recent publication of a text book by L. D. Miles, the father of value engineering, all bear witness to the belief held in the U.S.A. that value engineering can make an important contribution in the fight against rising costs. By contrast, the British technical press has been silent and professional institutions have almost entirely ignored the subject. It is therefore doubtful whether one British engineer in a hundred has ever heard it mentioned; if he has, he is likely to think of it in terms of a conventional cost-reduction scheme under the guise of a new name.

While it is true that value engineering also has as its ultimate aim the reduction of manufacturing costs so that, in this sense, it is a cost-reduction scheme, it is entirely novel in its approach to the problem and in the methods and techniques employed. Perhaps it is the failure to appreciate this basic difference that is responsible for the lack of interest in value engineering displayed, with very few exceptions, by British industry. Of cost-reduction schemes there are plenty, and no doubt they are successful to a greater or lesser degree. However, if we are to believe American claims—making due allowance for exaggerations fostered by an atmosphere of enthusiasm—that the savings achieved since the introduction of value engineering run into millions and millions of dollars, surely there is a case for scrutinizing the ideas underlying this concept and for ascertaining whether British industry could benefit by following the American lead.

Apart from commercial skills such as salesmanship and advertising, the main factors governing the saleability of industrial goods are quality, performance, reliability, appearance, and cost. The primary objective of value engineering is the reduction of costs without, however, sacrificing the standards of any of the other factors. No claims are made as to the novelty of this idea; indeed, it is so obvious that most engineering organizations, in one form or another, are performing work related to value engineering, although this activity will be covered by a different name. However, efforts in this direction are, in most cases, far too disjointed and the individual results are not integrated into a single full-time cost-reduction programme. Consequently, much of the potential benefit of these efforts is dissipated through the lack of a co-ordinated approach. What is new in value engineering, as it is understood in the U.S.A., is the co-ordination of many independent steps into one programme, administered by specialists whose sole responsibility is the attainment of the necessary functions at a minimum of cost.

The principal activities necessary for the creation of a finished engineering product are design, production, and purchasing. Let us now examine these areas separately, to see in which way they can contribute to cost reduction.

The design engineer will undoubtedly avoid the use of non-standard parts wherever possible, he will specify the largest tolerances commensurate with reliability, and he will, to the best of his knowledge, select the cheapest material commensurate with the duties of the part concerned. These are but a few examples of the cost-consciousness of the designer; yet his traditional preoccupation is quite naturally with performance and reliability. Quite naturally, too, he will heavily lean on precedent and past experience with similar designs, wherever possible, since this is clearly the safest path towards the achievement of his primary goal, i.e., reliable performance of the desired function.

The rôle played by the production engineer in relation to cost reduction is much easier to appreciate, since all decision-making and planning on his part must largely be dictated by cost. At the same time, it is normal practice in the production department to manufacture just what it is asked to produce, i.e., to carry out the instructions contained in the drawings received from the design office. Of course there are cases where exceptional difficulties encountered in the production of a particular part force the production engineer to refer the problem back to the designer, with the request to reconsider the design with a view to facilitating its production. Equally, if a particular production process is obviously very expensive, every effort will be made to eliminate it or reduce its costs so that again the designer may be called upon to circumvent a production bottleneck by design changes. The fact that production costs are not merely dependent on the competence of the production engineer and on the facilities of the plant available, but also on "design for production", has been recognized in the U.S.A. much earlier and much more widely than it has been in this country. While it is true that there are many signs that the engineering community is now becoming increasingly aware of the advantages to be gained from closer co-operation between design and production departments, this co-operation can only be regarded as a part of, but not as a substitute for, value engineering.

Purchasing is a function whose direct relation to costs need not be stressed. In short, the buyer's duty is to

* Chief Editor, The Engineers' Digest.

purchase the required raw materials, semi-finished products, or finished products at the right time and at the lowest cost compatible with the desired quality and acceptable delivery dates. His skill is centred around his ability to forecast market trends, his knowledge of likely suppliers, their reliability, the quality of their products, etc. If he is asked to purchase a particularly costly item, he may question the necessity of the expenditure and possibly suggest an alternative. On the whole, however, he will provide what he is asked to provide, since the technical justification for a purchase is outside his province. In other words, there exists no real co-operation between buyer and designer, so much so that the buyer has but a vague idea of the designer's reasons for requesting the purchase of a particular item, while the designer may have a completely distorted picture of the actual expenditure involved. This, value engineers argue, is not a healthy state of affairs and is bound to be reflected in hidden, unnecesssary costs.

What, then, is value engineering, or value analysis as it is sometimes called? Before answering this question, it should be understood that the term "value" in this context can be defined as the lowest possible cost for providing the required functions, consistent with good quality and reliability. At the risk of oversimplification, it is thus possible to consider value engineering as an organized approach to the problem of reducing actual costs to, as far as possible, their value equivalent. Unfortunately, value is not readily measurable. It can only be determined by comparison. To be useful in identifying and eliminating unnecessary cost, value becomes a measure of the degree to which the costs involved are justifiable. The value engineer, as distinct from the conventional cost-reduction specialist, is not so much concerned with the value of a part or product, but with the value of a function or functions. Thus, his whole approach to the problem of cost reduction is much more fundamental, and the question of how a particular part is produced in the most economical manner is transformed into the question of how a desired function can be performed at a minimum of cost.

Success in finding a satisfactory answer to this question will depend on the skilful application of certain well-defined procedures known as "value analysis techniques". In his book, L. D. Miles* lists these techniques —thirteen in number—in the form of slogans which may have their use as a means of indoctrinating the student, but are almost an insult to the intelligence of qualified engineers. For instance, the first of these slogans, "Avoid generalities" invites the retort "avoid banalities", while the last of the slogans, "Use the criterion, 'Would I spend my money this way?'" presupposes the reader to be a thoroughly irresponsible person. Technique No. 8 instructs us to "Get a dollar sign on key tolerances"—another typical example of the kind of claptrap jargon Americans seem to be so fond of. However, it would be a great mistake to let our automatic revulsion to potted slogans override our curiosity. Whatever our personal tastes, let us not lose sight of the fact that value engineering is now well established in American industry. Let us also hasten to add that Mr. Miles continues to elaborate the various value analysis techniques in great detail and does so with admirable success, so much so that, once the reader has managed to overcome his initial irritation, he will find this book fascinating, instructive, and convincing. Many practical examples of case histories, using the pictorial "before and after" technique and analysing the savings achieved, stimulate thought and direct it into unexpected channels. In short, this book cannot be too highly recommended; also, it is to the best of our knowledge the only comprehensive work on this subject.

* "Techniques of Value Analysis and Engineering", McGraw-Hill.

There is ample evidence that relatively large sections of British industry, from top management right down the scale, are victims of habit, afraid of change, or just too comfortable to bother to overcome the inertia of traditional thought. Tradition in the engineering skills is one of the greatest assets of this country, provided it is regarded as a foundation upon which to build a modern industrial structure which can hold its own against any competition. If tradition merely manifests itself as a trend to continue along the lines of time-honoured principles and techniques which nobody has taken the trouble to analyse in relation to their present-day usefulness, it is tantamount to stagnation. The concept of value engineering certainly breaks away from traditional thought, yet demands a high degree of traditional engineering skills. These remarks are not meant to suggest that value engineering is a panacea for industrial inefficiency, or to advocate its immediate and wholesale acceptance by British industry. In any case, there are many practical problems associated with its introduction and, as we shall see, value engineering is not a ready-made commodity.

The key to the successful establishment of a value-engineering programme lies in the proper selection of personnel and their integration into an existing organization. It must be appreciated that the introduction of any new idea into an existing set-up is always likely to be met with suspicion, unwillingness to co-operate, or even open hostility. This is one of the reasons why the most capable team of value-engineering specialists cannot possibly achieve worthwhile results without the wholehearted backing from management and without the willing and purposeful support from all departments concerned with the various phases of a product, from its inception to its sale. It will thus be the first task of value engineers to explain the various functions of value engineering to all concerned, to inspire confidence in the scheme, and to familiarize every employee with the way in which his activities will be affected; in other words, to sow the seed of value-consciousness throughout the organization.

It is probable that the success of value engineering in the U.S.A. would have come earlier than it actually did, had the protagonists of the idea realized from the outset the importance of creating an atmosphere of co-operation. To achieve this aim is no mean task, and the value engineer, who in this respect assumes the combined rôle of educationalist and diplomat, must be well endowed with the art of persuasion. Nothing could be more detrimental to the professional standing of value engineers than their success at the expense of others. In this connection, it must be understood that any reduction in product cost brought about by the creative efforts of value specialists must show up somebody to his disadvantage. After the event, a method of eliminating unnecessary costs may look very obvious, and somebody will find it convenient to blame somebody else for not having thought of it before, forgetting that the most obvious solution to a problem is often the most difficult to find. The mere fact of evolving a better value alternative, whether implemented or not, can lead to loss of prestige to everyone connected with established methods and design. This situation must, of course, be avoided

at all costs lest animosity and obstruction turn gain into loss. By making value engineering a team effort, giving credit to all concerned, difficulties of this nature should be greatly reduced, if not entirely eliminated.

There are, of course, other reasons why value engineering can only prosper as a team effort, foremost among which is the simple fact that the value engineer is not omniscient. At the beginning of work on an assignment, he must fully understand the function of any particular part or assembly under scrutiny, and clearly only the designer can fill in the gaps. Similarly, the value engineer must acquire a comprehensive knowledge of the production methods used or envisaged, and must for this purpose enlist the help of production engineers. In many cases, he must also consult the buyer as to alternative sources of supply and other trade information. Furthermore, the procurement of reliable cost data from the costing department is absolutely essential. In other words, fact-finding is the starting point of all value work, and true facts can only be obtained in an atmosphere of active co-operation.

Nevertheless, fact-finding from sources internal to an organization is not enough to ensure optimum results. In this connection, let the reader be reminded that only a relatively small amount of the total available specialized knowledge is readily accessible within one organization. A new process, developed to satisfy the needs of perhaps a small section of industry, is often adaptable to entirely different fields; yet, experience has shown that general recognition of its potentialities lags years behind its inception, for the sole reason that nobody took the trouble to seek beyond his own horizon. New materials fare no better, however suitable as substitutes for conventional materials and however advantageous from the cost standpoint they may be. It is not so much that their existence is not known, but rather that they are mistrusted and not given a fair chance. To illustrate this point, it must be admitted that the use of plastics in engineering is still on a comparatively modest scale. The reluctance of designers to specify plastics in a wider field stems partly from sheer conservatism and partly from the mistaken belief that these materials can replace metals without any change in design, dimensions, and tolerances—an attitude which almost without exception leads to disaster and consequently to the rejection of the material concerned. To quote Dr. Child of I.C.I., it is "technically and economically nonsense not to take full advantage of the particular processing characteristics and properties which a new material offers". Here, then, lies another field of endeavour for the value engineer who, through fact-finding from outside sources, can make a very real contribution to the economical operation of his organization by channelling specialized knowledge to those who can use it most effectively. Regular communication with existing as well as potential suppliers of raw materials, of semi-finished products, of nuts and bolts, in fact of all items purchased is thus part and parcel of the value engineer's work.

It will be apparent from what we have said that the value engineer must be an "all-rounder", though the depth of his knowledge, bearing in mind the wide diversity of the fields he has to cover, needs only be moderate. To keep abreast of developments, it is essential that he should find time for the study of technical literature, unlike a hard core of engineers in this country who take pride in announcing that they cannot spare the time to read technical periodicals. As they are beyond the reach of the written word, it is obvious that their voluntary seclusion from extraneous technical matters of the moment must ultimately militate against their own interests and against the interests of the company they serve. With the introduction of value engineering, however, this attitude cannot survive. Much benefit will accrue as a result of the vigilance of value engineers who, by diplomacy and persuasion, work towards the establishment of a more progressive outlook throughout the company.

As mentioned before, there is nothing fundamentally new in value engineering if each of its activities is viewed in isolation. The novelty is a matter of approach. If this is so, one might ask: Why are value engineers required at all? Why could not their functions be taken over by the various existing departments? Why add yet another specialist to the already imposing number of specialists employed by industry? In theory these are sound observations. In practice, however, the trend towards increasing specialization leads to the concentration of more and more knowledge into smaller and smaller areas, and, individually, the level of general engineering knowledge suffers as a consequence. Paradoxically, the value engineer could then be regarded as a "specialist whose speciality is that he is not specialized". He is not so much wanted for himself, but for what he can do to help others.

Once management has decided to take the plunge and give value engineering a chance, it will naturally expect to see almost immediate returns in the form of tangible savings. Although the wisdom of this attitude is arguable, it is nevertheless understandable. In the circumstances, the attention of value engineers will in the first place be focused on existing components which they suspect to contain a high proportion of unnecessary costs. Once a value-engineering programme is reasonably well established and cost-consciousness has infiltrated into the organization, requests for cost analysis should be encouraged from other sources. Since, in all such cases, present costs must be assumed to be known, it would appear that the scope of value analysis is confined to the improvement of existing designs, production methods, etc. This is certainly the case during the initial period of a programme but, when value engineering has been able to gain a firm foothold on the basis of proved effectiveness, it can be extended to encompass projects in the various stages of development. Here, it can be of at least equal usefulness, though the results achieved may not be so tangible. However, the lower is the stage of development of a product, the higher are the requirements for competence in value analysis techniques, so that, initially at least, emphasis should be laid on the elimination of existing unnecessary costs.

The direct output of value engineering is in the form of proposals contained in a concise report, which should set present production costs of a component against the cost of the value alternative developed. In no circumstances must the value engineer himself be allowed to make decisions in regard to the implementation of his proposals. Final decision-making must rest with management, however large may be the savings envisaged. In this respect, it must be clear that only management can decide the expediency of accepting a proposal, as the likely savings must be offset against such factors (to name only a few) as relations with customers and reciprocal suppliers, labour problems, and space utilization in the factory.

American experience indicates that value engineering

is sufficiently flexible to be introduced into large as well as into small businesses, irrespective of whether they are engaged in large or small production runs. As regards the return that can be expected, published figures vary. A ratio of 20 to 1 seems to be the average, i.e., the savings realized are 20 times the expenditure involved. How much reliance can be placed upon this figure we are unable to say. However that may be, there can be little doubt that the savings that have been achieved are still substantial.

In these days, when we are constantly being reminded that Britain must export more and that the European Common Market will provide the necessary opportunity *if our prices are right*, can we afford to ignore such a promising method of cost reduction in what will undoubtedly be a highly competitive market?

Automatic Tension Regulator for Cold Rolling Mills

By V. S. VISOCHANSKII

From *Vestnik Elektropromyshlennosti*, Russia,
No. 10, 1961,
pp. 38-41, 5 illustrations.

PROBLEMS in connection with the control of the tension of processed materials such as strip and wire are of great importance in many applications, but the present article is limited to consideration of the operation of automatic tension control in cold rolling mills, in which the control of tension of strip is usually ensured by a regulator which operates as a function of the current or power input in the winding-reel motor. This arrangement is, however, complicated and, at the same time, does not ensure an accurate control of tension, inasmuch as the input power of the motor is not only absorbed in producing strip tension, but also in covering the losses in the motor and transmission.

For this reason, and notwithstanding the incorporation of compensating devices in the control system, strip tension tends to differ from specified values, particularly in the case of small settings. The regulators used have the disadvantage of acting only after a change in tension has occurred and cannot foresee or prevent a deviation in tension. Consequently, they cannot cope with disturbances of short duration produced during each revolution of the winding reel as a result of its out-of-roundness or eccentricity, or as a result of unevenness of strip thickness. In fact, investigations have shown that the amplitude of variations in tension can often reach ± 10 to $\pm 20\%$, and in some cases can even exceed $\pm 40\%$ of the specified value. Similarly, jerking of the strip caused by sudden changes in tension can lower its quality by magnifying its inequalities in thickness.

The main difficulty in producing accurate tension regulators arises from the fact that strip tension is related to the relative speeds of the rolling mill and the winding reel. The difference between the normal and the limiting elongation of the portion of strip travelling between the rolling mill and the winding reel does not exceed a few millimetres, whereas the actual rolling speed is of the order of tens of metres per second. It is apparent, therefore, that even coarse regulators of tension must synchronize the mill with the winding reel quite accurately.

To exclude any deviation in tension, it is necessary to change the conditions of producing tension, as well as the method of controlling it. The dependence on the ratio between the speeds of the mill and winding reel must be eliminated, and a method of accomplishing this is achieved by the tensioning device shown in Fig. 1, in which a swinging tensioning roller (1), with an arm actuated by a mechanism (2), is located between the rolling mill (3) and a deflecting roller (4). The tensioning roller produces a small reserve loop of strip, generating a tension that is balanced by the motors of the rolling mill and the winding reel (5). Proper selection of the mechanical characteristics of the actuating mechanism (2) will ensure an identical strip tension for various positions of the tensioning roller (1), this being obtained by plotting the equivalent tension forces acting in the loop and the active component of pressure exercised by the action of the roller on the strip at different intermediate positions. The slope of the torque curve, as well as the magnitude and position of its maximum value, will depend on the relative disposition of the rollers and the geometrical dimensions of the actuating mechanism. With a small loop, the pressure of the roller (1) is small; as the size of the loop increases to a certain value, the pressure increases, but beyond this value it starts to decrease again. This form of mechanical characteristic is exhibited by solenoids with a rotary armature, making them suitable for application in an actuating mechanism of this type.

The characteristic of the actuating mechanism in this tensioning device produces on the strip a variable pressure which acts immediately with any change in position of the tensioning roller, ensuring constant strip tension. In the case of differences in the speeds of the rolling mill and winding reel, only the position of the tensioning roller and the size of the loop are affected, but the tension itself remains constant.

The speed of the winding-reel motor is automatically controlled in relation to changes in the position of the tensioning roller, so as to avoid the enitre disappearance or excessive formation of the loop as a result of prolonged difference in speeds. For this purpose, the rotation of the armature of the actuating solenoid is transformed into a control voltage by a selsyn, this potential being compared with a reference voltage, and the difference amplified to act on the voltage and current of the winding-reel motor. In this way, a closed-loop control system is formed which follows the position of the roller, detects the presence of disturbances and, because of the

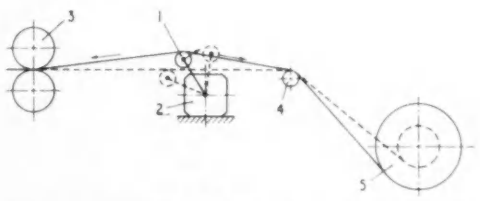

Fig. 1. Schematic arrangement of the new automatic tensioning device.

loop, has a sufficient time lag to eliminate the differences in speeds before they affect tension. In fact the presence of only a few centimetres of loop provides sufficient time lag to regulate the speed of the winding-reel motor.

The method of amplification used and stabilization of the system are simplified, because its coefficient of amplification is proportional to the permitted error of travel, i.e., to the size of the loop, instead of to the elastic elongation of the strip. The amount of tension is controlled by changes of current in the solenoid and can be regulated according to any desired law, tension settings becoming practically unlimited. During adjustments, the solenoid is de-energized and the tensioning roller is in its lowered position. The solenoid has the additional advantage of being small, requires little power, and has a torque/inertia ratio many times higher than it is in electric motors.

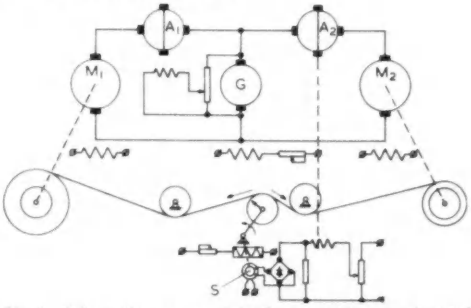

Fig. 2. Schematic arrangement of a complete experimental installation for coiling aluminium strip.

To design a suitable solenoid, it is necessary to know the maximum torque it has to provide, this being proportional to the tension and maximum size of the loop. When the disposition of the deflecting and tensioning rollers, as well as the armature of the solenoid, ensures a swing of the tensioning roller through an angle of 90 deg., the required mechanical characteristic is nearly sinusoidal.

For the purpose of investigating this method of automatic tensioning, a special solenoid was designed and constructed. This solenoid, which weighed 40 kg, had an armature with an active length of 200 mm and a diameter of 59 mm, a maximum continuous torque of 7 kgm, and an input power of 0·65 kW. The solenoid was used in the mock-up installation shown schematically in Fig. 2. in which M_1 and M_2 are two 5·6-kW. 1000/2000-rpm motors operating alternately for coiling and decoiling aluminium strip. These motors are fed by two 60-V 16-A rotary amplifiers A_1 and A_2, and by a common 115-V. 1·5-kW generator G incorporated into the circuit to take full advantage of the speed of the motors. The tensioning device was located between the motors. with the solenoid mounted at the side of the rollers, although it is desirable in an actual rolling mill to mount it below the strip. The armature of the solenoid is connected to a selsyn S at the side opposite to that of the tensioning roller. The speed and direction of motor M_1 are controlled by the voltage of the generator G, which is in turn excited by the amplifier A_1. Motor M_2 is synchronized with motor M_1, the automatic speed regulation of motor M_2 being obtained through the action of the selsyn S in conjunction with amplifier A_2.

The experimental mechanical characteristics of this arrangement are shown in Fig. 3, in which strip tension is plotted as a function of the angle of rotation of the solenoid armature for various values of solenoid current. From Fig. 3 it will be seen that, with solenoid currents between 0·3 and 4 A, the corresponding regulation of tension is between about 8 and 330 kg, and the absolute error of rotation of the solenoid armature between 30 and 75 deg. does not exceed 10%. The degree of rotation of the solenoid corresponds to a change of 18 mm in the length of the loop. A reduction in the range of tension regulation results in a smaller error, i.e., between 1 and 2%. The dynamic error of the regulator related to the energy absorbed by acceleration of the tensioning roller and solenoid armature is very small. This can be explained by the low inertia of the tensioning device and the limited acceleration of the solenoid. For example, during acceleration of the winding speed to 19 m/sec in 8 sec, the armature rotates through less than 30 deg.

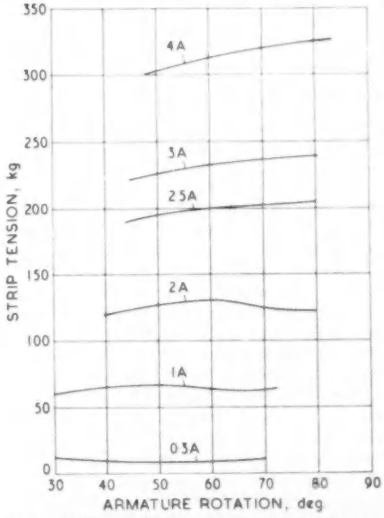

Fig. 3. Characteristics of the experimental installation, showing strip tension as a function of the angle of rotation of the solenoid armature for various solenoid currents.

In operation, the coil of aluminium strip is mounted directly on the shaft of one of the motors and is passed through the rollers and fixed to the winder on the other motor. In the initial position, the solenoid is not energized, so that the tensioning roller is in the lowered position because of its own weight, the voltage of the selsyn being zero. After switching on, the armature of the solenoid tends to lift the roller, but rotation of the armature results in a voltage increase in the solenoid, causing the coiling motor to tension the strip and balance the pressure of the tensioning roller. The tensioning roller rises as the speed of the decoiling motor increases, thus building up a reserve of loop. The result is a speed increment in the coiling motor, causing the size of the loop to decrease, while the speed of the coiling motor decreases with increasing coil diameter.

It should be noted that, when using this equipment for winding aluminium foil of 0·05 mm thickness, the speed of 19 m/sec attained was higher than that normally used for aluminium foil. The conditions of the tests were further aggravated by the fact that the solenoid operated under a tension of 17 kg, although it was designed to develop a thrust of 400 kg. In addition,

winding operations were carried out under conditions of artificially induced shock loads. However, despite these conditions, as well as the high specific tension of 6 kg/mm² and the repeated winding of the foil at speeds in excess of 1000 m/min, no breakage of the foil occurred, all jerking movements being damped out by the tensioning roller.

In conclusion, it is considered that this tensioning system constitutes a complete solution to the problem of automatic tension control and has the advantage that the design of the tensioning mechanism and of the electrical control circuits is simple and reliable. Furthermore, its field of application is not limited exclusively to cold rolling mills, as it can also be used successfully in other applications, including the processing of wire, ribbon, paper, and textiles.

The Wear Characteristics of Oscillating Bearings

By C. A. BROCKLEY

From *Wear*, Netherlands,
Vol. 4, No. 5, September/October 1961,
pp. 333-344, 9 illustrations.

KINEMATIC linkages of various types incorporate bearing elements which are subjected to oscillatory motion, the crank-and-rocker mechanism, the double-rocker mechanism, and the roller-transmission chain being well-known examples. The oscillating bearing can operate in the régime of mixed lubrication and, as a consequence, the question of wear is of interest. In some mechanisms, wear leads to loss of accuracy, and in extreme cases the change in dimension produced by wear can reach a stage where the mechanism becomes operationally useless. For example, excessive wear of the pins and bushes of roller chains can have a pronounced influence on the effectiveness of power transmission.

The oscillating bearing can be classified according to the type of load application. The small-end connecting-rod bearing typifies the case of oscillatory motion and dynamic load application. On the other hand, there are examples of unidirectional steady-load application and oscillatory motion, and the present paper is concerned with the wear characteristics of a bearing of this type.

Some previous experimental and theoretical studies have been concerned with the characteristics of oscillating bearings. Thus, Fogg and Jakeman[1] made an experimental investigation into the oscillating bearing in connection with the boundary friction properties of a variety of oils. The experiments in this instance were conducted with a hardened steel journal operating in a hardened steel bush provided with helical grooves. It was considered that the grooves assisted in reducing possible hydrodynamic effects, thus giving the boundary-lubrication characteristics required for the experiments. In this work it was observed that friction had a maximum value at the start of oscillation, and a minimum value at mid-oscillation, at a time corresponding to maximum sliding velocity. In explanation of this behaviour it was postulated that isolated, microscopic hydrodynamic "wedges" existed and that these hydrodynamic effects tended to increase as the velocity increased, thereby reducing friction. Fogg and Jakeman concluded that mixed-lubrication conditions prevailed throughout their work.

More recently, Glaeser and Allen[2] reported experimental results for grooved, grease-lubricated bearings subjected to an oscillatory motion of ± 45 deg. amplitude at a frequency of 12 cpm. In these studies it was noted that steady load gave the friction characteristic observed by Fogg and Jakeman. Load reversal produced a similar friction curve, but the drop in friction at mid-oscillation was less pronounced.

Summarizing previous work in this field, it can be concluded that mixed-lubrication conditions appear to predominate in the case of unidirectionally loaded bearings and that full hydrodynamic lubrication is difficult to achieve. A comparatively small amount of work has been concerned with the wear characteristics of oscillating bearings.

In the present work, ungrooved hardened steel bushes were used in conjunction with hardened steel pins in order to study the influence of hardness, sliding velocity, clearance, and surface finish on the wear characteristics of the bearing. Friction and load-capacity tests were also conducted.

Experimental Apparatus

Wear research results are critically sensitive to experimental environment[3] and, as a consequence, some considerable attention must be given to the design and construction of suitable apparatus. The salient details of a typical test station in the apparatus developed are illustrated in Fig. 1. The nut, rod, and spring assembly (*a*) was used to load the bottom test-bearing assembly,

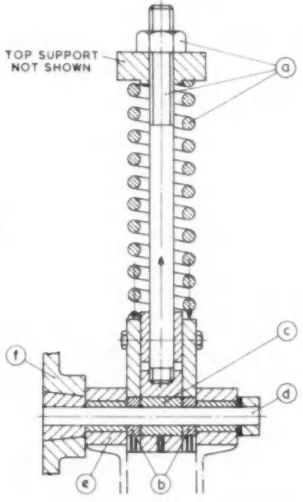

Fig. 1. Section of a single station in the oscillating bearing test machine.

which consisted of two outer bushes (*b*) and a single inner bush (*c*) with the three bushes operating on a single pin (*d*). The two outer bushes were loaded in opposition to the centre bush, thus giving a compact system subject to minimum pin deflection. The magnitude of the load was assessed by measurement of the spring deflection,

the use of identical outer test bushes giving a valuable check on experimental wear results. The complete test-station assembly was supported by outboard bearings (*e*), and a linkage system (*f*) was used to oscillate the test pin. The complete machine consisted of six identical test stations of this type. A constant-speed motor, vee-belt, and gear system gave a frequency of oscillation of 8·4 cps. By adjustment of linkage ratios, the angle of oscillation could be varied in the range of 0 to 32·5 deg.

The steel bushes had a bore of $\frac{3}{4}$ in. and were respectively $\frac{1}{2}$ in. and $1\frac{1}{2}$ in. long. These dimensions corresponded to length/diameter ratios of 2·0 and 0·66. Central oil holes provided access for gravity-fed lubricant to the unloaded side of the bushes.

The pins and bushings were manufactured from steel whose chemical composition was: 0·20% C 1·75% Ni, 0·30% Cr, 0·38% Mo, 0·19% Si, 0·16% Mn, and 0·014% P. The nickel content of the steel reduced the possibility of non-uniformity in heat treatment and assisted in minimizing surface-cracking defects during grinding. After rough machining, the specimens were carburized at 900°C and air-cooled; subsequently, they were reheated to 850°C, and oil-quenched. A hardness reduction was obtained for certain specimens by tempering. Finally, all specimens were precision-ground to final dimensions.

Test Results

Early in the research programme, the lubrication regime in which the bearings were operating was established by means of friction measurements, $1\frac{1}{2}$-in. long bushes being used for the tests. A modified test station, which had the outer bushes replaced by ball bearings, was used for this study. Friction torque was measured and the bearing temperature was determined by means of a thermocouple located near the working surfaces.

Fig. 2 shows a typical graph of coefficient of friction f plotted against Sommerfeld number Δ, defined as

$$\Delta = \left(\frac{D}{C}\right)^2 \frac{\mu U}{P}$$

where μ is the absolute viscosity, U is the maximum sliding velocity, P is the load per unit area, C is the diametral clearance, and D is the nominal bearing diameter.

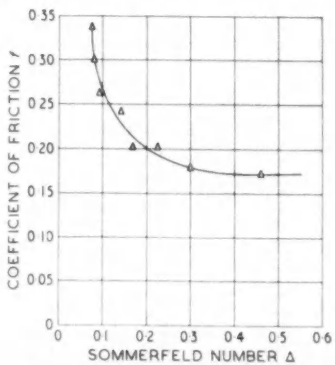

Fig. 2. Coefficient of friction plotted against Sommerfeld number for an oscillating bearing operating with a maximum sliding velocity of 4·68 ips and a clearance of 0·0015 in.

At low Δ-values, a high coefficient of friction is apparent, but at large Δ-values the curve tends to a minimum friction value of 0·17. The curve suggests that mixed lubrication tends to persist to high Δ-values without the distinctive rise in friction which occurs in full hydrodynamic lubrication. However, Δ-values larger than those investigated may show the rise in friction associated with hydrodynamic action.

A direct-measurement technique utilizing a Watts "Microptic" measuring machine was evolved for the assessment of wear. Wear measurements were made at regular angular intervals around the circumferences of the pins and bushings at axial positions corresponding to the centre of the pin-and-bush combinations in each case. The following results (with the exception of those referring to wear distribution) are reported in terms of mean values, inasmuch as the wear readings at discrete angular positions around the circumferences of the specimens were averaged. In this way, sole dependence was not given to a single reading, and each of the mean wear figures reported represents the average of some sixty individual results.

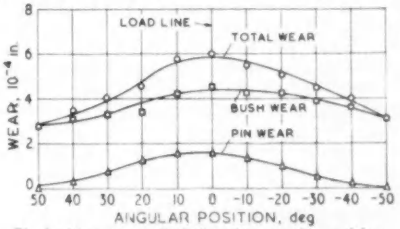

Fig. 3. Mean wear plotted against angular position.

Typical wear-distribution curves are shown in Fig. 3, from which it will be noted that pin wear was low compared with bush wear. During the oscillation, a given point on a moving pin was subjected to variable pressure, whereas an equivalent point on the stationary bush was under constant pressure, tending to promote high bush wear. The curves also demonstrate the establishment of "local conformity" by the wear process. As wear progresses, local contact conditions are improved and the load is distributed over a larger area.

It was also found that initial wear was accomplished fairly rapidly, and all the results reported later represent conditions at the end of 450,000 cycles, which was well within the secondary stage of wear.

The ultimate load capacity of an oscillating bearing is critical in applications where loads are extreme and lubrication is defective. Ultimate load capacity or seizure can be classified as an extreme case of the surface damage associated with wear.

Cleanliness of mating surfaces is a contributing factor in seizure; if a protective film of oil, boundary lubricant, or oxide layer is maintained, then intimate metal-to-metal contact is prevented. However, under extreme conditions of load, these protective layers can be destroyed, thus leaving the surfaces open to excessive local welding.

Bowden and Tabor[4] have shown that high hardness will produce a great temperature rise and that surfaces of dissimilar hardness will have a local temperature rise governed by the surface of lower hardness. In the process of seizure, however, it would appear that other variables, such as surface finish, clearance, and the viscosity of the lubricant, must also be taken into account. Surface finish has some influence on the maintenance of full hydrodynamic lubrication[5], and it is logical to suppose that microscopic surface geometry

will affect the load capacity in the region of mixed lubrication.

To investigate the influence of hardness and surface finish on seizure, load-capacity tests were conducted at a maximum sliding velocity of 5·36 ips, corresponding to an angle of oscillation of 32·5 deg. The test frame was provided with high load-capacity bronze bushes in the outer forks, and the inner 1½-in. long bushes were the test specimens, the clearance in all cases being 0·001 in. Bulk bearing temperatures were obtained by embedding a thermocouple $\frac{1}{16}$ in. below the bush surface. In all experiments, a 30-min no-load running period preceded the seizure test to ensure initial steady-state conditions. Following this initial period, equal increments of load were applied in equal increments of time.

The test results in Figs. 4 and 5 are plots of the "load number" (the inverse of the Sommerfeld number) in terms of time. Fig. 4 refers to an assembly in which the pin was softer than the bush, the average difference in Vickers pyramid hardness being about 420. Curve (*a*) was obtained with a centre-line average surface finish of 22 micro-inches, and curve (*b*) with a surface finish of 14 μin. Fig. 5, on the other hand, applies to the case where the pin was harder than the bush, the average hardness difference being about 15. In this illustration, curve (*a*) was obtained with a surface finish of 25 μin., and curve (*b*) with 15 μin.

A comparison between Figs. 4 and 5 shows that seizure resistance increases with an increase in the hardness difference between pin and bush. In Fig. 4, the failures consisted of a series of small local seizures distributed over the surface, while in Fig. 5 failures were characterized by a single local seizure which penetrated into the substructure of the surface. It is suggested that the higher load capacity of the softer pins is attributable to the formation of relatively weak surface junctions which failed at the pin surface without an excessive local temperature rise. In the case of small hardness differences between pin and bush, strong junctions were formed which tended to promote high temperatures. In general, it can be concluded that unequal hardness conditions are to be preferred, since such conditions are conducive to high load capacity coupled with relatively mild surface damage at final seizure.

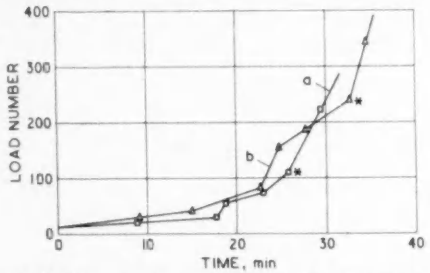

Fig. 4. Load-capacity tests with the pin softer than the bush, the asterisks denoting seizure.

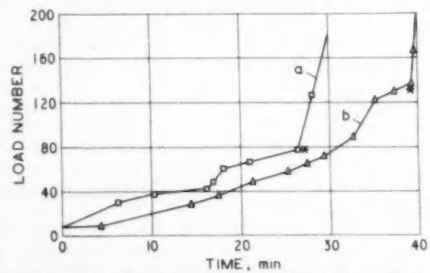

Fig. 5. Load-capacity tests with the pin harder than the bush, the asterisks denoting seizure.

The influence of surface finish is also evident from Figs. 4 and 5, since in all cases the smoother initial surface finish resulted in improved load capacity. All the load-capacity curves exhibit an interesting characteristic—first a slow and uniform increase, and then a sharp rise of short duration followed by another slow increase to the seizure point. It is thought that this rise signifies a minor seizure which stabilized for a period before final failure.

There is general agreement in the literature concerning the role of hardness in relation to the wear of metals, and it can be concluded that high hardness imparts good wear resistance. As a consequence, it is to be expected that surface damage (wear or metal transfer) will vary more or less directly as hardness. In the case of a steel surface, hardness is related to its metallurgical structure, and these two factors must be assessed together.

Typical experimental results of the wear resistance of steel surfaces in relation to their hardness and metallurgical condition are given in Fig. 6, in which mean total wear is plotted against the difference in hardness, expressed in VPH, between pin and bush. The condition of equal hardness resulted in minimum wear, although the increase in wear with increasing hardness difference is small until a differential value of 200 is reached, whereupon the curve tends to rise somewhat more rapidly. A metallurgical examination of pin-edge structures demonstrated that the hardest pins possessed a martensitic structure with some evidence of grain-boundary carbide. In the lower hardness ranges, the grain-boundary carbide was considerably more pronounced. These structures were considered to be normal for the type of steel used.

While load-capacity experiments indicate that a hardness difference is desirable, hardness results suggest that a great hardness difference is not acceptable, since it produces a comparatively great increase in wear.

Clearance is related to hydrodynamic action, rate of lubricant supply, and contact conditions between pin and bush. Obviously, an adequate oil supply is necessary for the maintenance of uniform mixed-lubrication conditions and for removing abrasive wear debris from between the surfaces. According to Shaw and Macks[6], the rate of lubricant flow Q in the case of a central oil hole is given by

$$Q = \frac{c^3 p_0}{3\mu} (1 + 1{\cdot}5\eta_i^2) \tan^{-1} \frac{2\pi r}{L}$$

where c is the radial clearance, p_0 is the supply pressure, μ is the absolute viscosity, η_i is the eccentricity ratio, and r and L are respectively the nominal bearing radius and length. In this equation, clearance emerges as an important variable since it appears to the third power.

Under conditions of mixed lubrication, contact occurs at isolated surface asperities in a zone of contact determined by the bulk deformation of the surface material. In many internal-contact design calculations, the projected area is used to predict average bearing pressures. This procedure is open to certain objections, since no recognition is given to the possible effects of clearance. The Hertz equations can give some guidance in predicting initial local contact conditions for relatively

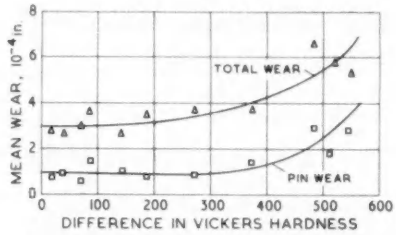

Fig. 6. Mean wear as a function of the difference between the Vickers pyramid hardness between the pin and the bush.

close-fitting bearing elements. Normally, these equations are limited to small areas of contact, but their use in this case provides a somewhat more realistic assessment of initial contact conditions than the projected-area calculations. After initial wear has established some measure of bearing conformity and a relatively large area of contact exists, the Hertz equations become less reliable and the projected-area criterion is more accurate.

The modified Hertz equation for width of contact b is

$$b = 2{\cdot}15 \sqrt{\frac{W D^2}{LE C}}$$

where W is the load, L is the bearing length, D is the nominal bearing diameter C is the diametral clearance, and E is the modulus of elasticity. Hence, b varies inversely as the square root of C and, at small values of C, the contact width becomes large.

Experimental work was conducted to determine the change in wear produced by variation in clearance, with oil consumption being measured. In these experiments, some of the clearances were large to make a complete study of wear relationships. Consistent results were obtained, and the results from one typical test are given in Figs. 7 and 8, conditions in this case being a length/diameter ratio of 0·66; a maximum sliding velocity of 5·36 ips; a bearing load of 600 psi; an average hardness of pin and bush of 810 VPH (20 kg); and a centre-line average surface finish of 13 μin.

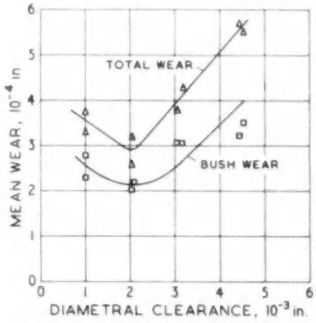

Fig. 7. Mean wear as a function of diametral clearance.

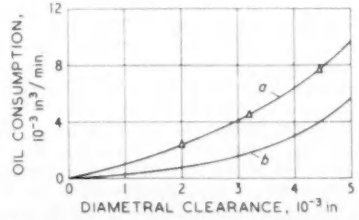

Fig. 8. Oil consumption as a function of diametral clearance, curve (*a*) referring to experimental values and curve (*b*) to calculated values.

Fig. 7 illustrates the wear/clearance relationship, and Fig. 8 shows the actual oil consumption compared with a plot obtained from the oil-flow equation. It is evident from the wear results that an optimum clearance condition exists at $C = 0{\cdot}002$ in. At a clearance of less than 0·002 in., it can be postulated that the reduced clearance prohibited an adequate supply of lubricant, so that wear tended to increase. At a diametral clearance of more than 0·002 in., the oil supply was adequate, but the contact conditions were excessive (see modified Hertz equation), thus giving increased wear. With reference to oil supply, the results suggest that the central-oil-hole equation underestimates oil flow. It can thus be concluded that an optimum clearance for minimum wear exists for the oscillating bearing, and that a balance must be achieved between lubricant supply and contact factors.

As regards the relationship between initial surface finish of the bearing and wear, it was found that, under otherwise equal conditions, smooth surfaces obtained by lapping resulted in increased wear as compared with rough finishes obtained by grinding.

A detailed account of the surface-finish results is beyond the scope of the present paper and will be reported later as part of a general study of surface finish in relation to wear. It is interesting to note, however, that good wear resistance apparently requires a rough finish, whereas the seizure results indicated that a smooth finish gives the best results.

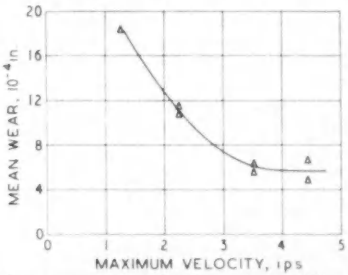

Fig. 9. Mean wear as a function of maximum sliding velocity.

With regard to the relationship between wear and maximum sliding velocity, the typical test results depicted in Fig. 9 indicate that low sliding velocities resulted in great wear, and that wear diminished to a constant value as the sliding velocity was increased. A similarity thus exists between these results and the friction results given in Fig. 2. It is suggested that microscopic hydrodynamic effects also explain the wear behaviour under conditions of velocity variation.

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Anomalous Cathode Erosion with Arcs of Millisecond Range during Spark-Machining

By J. M. FELDMAN and E. M. WILLIAMS

In this paper, the third of a series concerned with the electrode erosion phenomena accompanying low-voltage discharges in liquid dielectrics, data are given of the results of investigations into the significant phenomena occurring during spark-machining. As distinct from the pulse durations in the microsecond range used for machining sintered carbides and high-temperature alloys, consideration is mainly given to the relevant erosion phenomena for transient arcs in the millisecond range, as used for machining tool steels and soft and easily machinable materials such as brass.

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pp. 523–528, 5 illustrations.

THE fundamental phenomenon employed in spark-machining is the electrode erosion accompanying an electrical discharge. Considerable investigations have been made in connection with the effects of discharge duration, electrode polarity, pulse-current amplitude, the use of liquid or gaseous dielectrics, discharge repetition rate, etc. on the speed, accuracy, and surface finish attained in machining. However, these investigations have generally been concerned with the phenomena accompanying very short discharges, because such discharges are known to be effective in the machining of sintered carbides and high-temperature alloys. For such machining it has been shown that most favourable results are obtained when the discharge polarity is such that the workpiece is positive and the tool electrode negative, when the discharge current is as nearly unidirectional as possible, when the pulse durations are in the microsecond range, and when the relation between pulse duration and repetition rate is such that the duty cycle is low.

Major changes have recently taken place in the fields of application of spark machines, new applications being widely concerned with the machining of tool steels and even of soft, easily machinable materials. A number of machine tools have appeared in which the power supplies deliver high-duty-cycle, millisecond pulses of somewhat lower current but higher average power than machines employed with carbides. Moreover, in some of these units, the discharge polarity is often such that the tool electrode is positive, while the workpieces are negative. In view of the apparent success of these machines, it seemed desirable to study experimentally the relevant basic erosion phenomena for transient arcs in the millisecond range. Because the favourable results obtained with a reverse polarity discharge appeared to be completely anomalous in view of earlier studies, particular emphasis was placed on cathode phenomena.

Measurements of electrode erosion accompanying arc discharges of the duration and magnitude employed in spark-machining are usually conducted in one of two ways, i.e., (1) after a single discharge, the crater areas and depths can be measured optically and the eroded volume computed, or (2) after a series of discharges, the erosion can be determined by loss of weight measurements. However, in the case of long-duration discharges, and especially for cathode craters, optical measurements are too inaccurate to be practical because of the highly irregular form of the electrode craters. After examining various alternatives, the authors decided to employ sequential pulses separated from one another by several hundred pulse durations. A pulse generator was designed to deliver "rectangular" pulses of current with durations from 0·1 to 11 milliseconds and currents in the range of 10 to 200 A. Arc current and arc-voltage drop were monitored with a cathode-ray oscilloscope.

The electrode materials used in these tests were carbon, copper, tungsten, molybdenum, brass, and iron, and were selected so that the effects of single parameters (thermal properties, atomic mass, melting points, etc.) could be examined. Some such procedure is essential in order to reach well-defined conclusions from the mass of apparently unrelated data that otherwise results from tests with many independent variables.

The first experimental problem was concerned with the reported anomalous cathode erosion itself. Any favourable operation of electric-spark machine tools with negative workpiece polarity implies that, in some circumstances, cathode erosion exceeds anode erosion. It was originally suggested that, although anode erosion exceeds cathode erosion for discharges in the microsecond range, there would be an "erosion-ratio" reversal for discharges in the millisecond range. Experimental results indeed show that, with a steel cathode and a brass anode, for instance, the weight loss in the cathode greatly exceeds that in the anode; however, the ratio of eroded steel to eroded brass is even greater when the steel electrode serves as the anode and the brass electrode as the cathode. Moreover, the amount of steel removed in a single discharge is greater with the steel serving as an anode.

TABLE I: EROSION OF STEEL AND BRASS ELECTRODES PER 1000 ARCS

Current [A]	Arc Duration [msec]	Erosion [mgm/1000 arcs]			
		Steel Anode	Brass Cathode	Steel Cathode	Brass Anode
85	1	80	12	9	5·5
85	10	1450	200	75	12·1
200	1	No data		70	66*
200	10			390	170

* Not well established

The results of comparative tests of the erosion of steel and brass electrodes per 1000 arcs are given in Table I for currents of 85 and 200 A and arc durations of 1 and 10 milliseconds. These results suggest that, with a steel workpiece and a brass tool, the most rapid spark-machining will take place with what has come to be known as "conventional" polarity, i.e., a positive workpiece and a negative tool. Since it has evidently been more satisfactory to operate with a reverse polarity, there must be some significant effects not disclosed by the data in Table I. Since tool materials other than brass are frequently employed (copper and carbon, for instance), similar tests were conducted with a wide variety of

materials. With low-melting-point anode materials, such as zinc, lead, and magnesium, there was no steel-cathode erosion whatever. With relatively refractory materials, results of the same form as those in Table I were obtained, with, however, erosion of the steel cathode generally increasing with decreasing atomic weight of the anode.

The superiority of the operation with reversed polarity appears to lie not in a more favourable erosion ratio, but rather in the dynamics of the discharge gap. This was disclosed by oscillographic traces for a discharge gap with a steel anode and a brass cathode, and for a discharge gap with a steel cathode and a brass anode. In the former case, the discharge-voltage drop was erratic and often characterized by frequent short-circuits. In the latter case, the discharge was uninterrupted.

The electrical characteristics of the discharge gap are important because periods of short-circuiting presumably correspond to an absence of machining action, wasted energy, etc., and the discharge-gap voltage is commonly used as the information input, or part of the information input, to the servomechanism which automatically controls tool position.

The factors which cause the erratic discharge characteristics mentioned in the case of a discharge gap with a steel cathode and a brass anode are unknown. An important factor, however, is thought to be the "upheaval" of electrode material to form short circuits, the surface scratches on one electrode being imprinted on the upheaved material of the other. These effects may be avoided by the use of higher prespark-over voltage, which permits larger electrode spacings. Such spacings, however, may be undesirable because of poorer machining tolerances, lower electrical energy efficiency, and reduced erosion. It has been shown that, as the spacing increases beyond the very small values of 0·0005 to 0·005 in. employed in typical tools, the volume of material removed rapidly decreases.

Although these data account for the advantages of employing anomalous polarity for the machining of steel workpieces, they provide no explanation for the erosion effects accompanying this polarity. These erosion effects become very puzzling when it is realized that, for cathode materials other than iron or a ferrous alloy, with melting points higher than 1000°C, such as copper, molybdenum, and tungsten, cathode erosion drops so low as to be very nearly immeasurable by the weight-loss method. Incidentally, the erosion effects are independent of whether the cathode material is ferromagnetic or not. This point was studied because a differential effect exists in anodes, at least for discharges in the microsecond range.

As a result of the interesting anomaly of high cathode erosion associated with ferrous materials alone, some further investigation was made of the quantitative details of steel-cathode erosion and of possible underlying physical phenomena. Typical data of the erosion of steel cathodes in terms of the cathode weight loss ΔW as a function of arc-discharge duration t for various anode materials, using a current of 85 A and kerosene as the dielectric, are given in Fig. 1. The data correspond to a functional behaviour in which erosion increases exponentially with time up to a rather sharply defined knee, or to expressions of the form

$$\Delta W = A\epsilon^{\alpha t} \quad .. \quad .. \quad (1)$$

where ΔW is the cathode-weight loss [mgm per 1000 arcs], A and α are constants depending on the anode material, discharge current, and dielectric composition, and the arc-discharge duration $t \leq t_c$, where t_c is the critical arc duration at which the knee appears.

In seeking a physical explanation of the anomalous cathode-erosion phenomenon in ferrous alloys, previous scientific studies are of little direct assistance. It seems clear that, immediately after spark-over, there are very high current densities and that thereafter the current densities decay. The mechanisms accounting for electron emission and the predominant factors in electrode erosion may well change as time passes; indeed, the existence of a knee in curves such as those in Fig. 1 is highly suggestive of shifts in significant physical effects. Moreover, comparisons of observations of electrode erosion for currents of, at most, a few hundred amperes and of those at tens of thousands of amperes, suggest that magnitudes of total current, as well as current density, may be correlated with significant physical effects. Whatever may be the mechanism of material removal at the cathode, it must be closely related to the physical conditions in the discharge at and adjacent to its cathode terminus, since the electrical conditions, in particular the resistive power loss, within the cathode itself are insufficient to account for the material removal. The physical conditions in the discharge adjacent to the cathode are unknown, but significant hypotheses result from their relationship to electron emission.

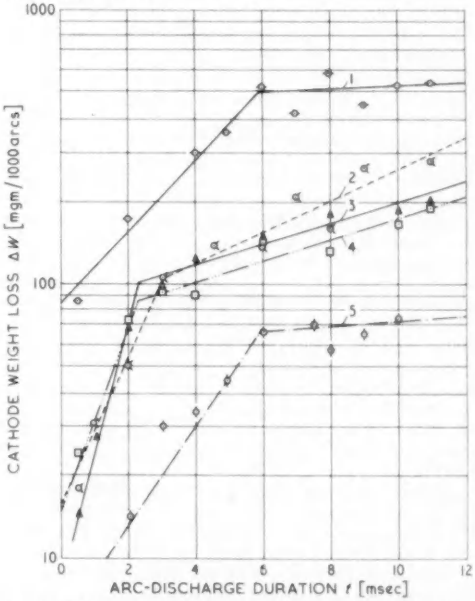

Fig. 1. Weight loss ΔW of a steel cathode as a function of arc-discharge duration t, using a spacing of about 0·001 in., a current of 85 A, a kerosene dielectric, and anodes of (1) carbon, (2) copper, (3) molybdenum, (4) tungsten, and (5) brass.

Explanation of the extremely high emission current densities observed at the cathode surface has been difficult, especially since these current densities are established in the course of the first few nanoseconds while the cathode is still cold. Several important theories have been propounded by Lee[1] (field emission from a hot cathode), by Von Engel and Robson[2] (a field-assisted process at a hot cathode), and by Cassie[3] (a

lowering of work function because of a pinch-effect induced charge depletion). Of these, only the theory of Cassie accounts for the rapidity of establishment of high current-density emission in the absence of temperature rise.

If it is assumed that initial cathode emission takes place as suggested by Cassie, and that the mechanism proposed by Von Engel comes into play as soon as the cathode material develops an appreciable vapour pressure, it seems reasonable to assume for the charge under discussion in this paper a model in which the discharge column comprises a neutral plasma extending from the anode to a region very close to the cathode, with most of the discharge voltage developed across the region immediately adjacent to the cathode. It is further assumed that the cathode fall initially occurs within about one ion mean free path of the cathode.

According to this model, ions bombard the cathode surface and the ion energies are between 10 and 20 eV—a very large energy in terms of thermal energies. At the site of the ion-cathode collision a local disturbance is created which can best be described by using the quantum concept of a phonon. The energy and momentum of this phonon have the proper values to satisfy the requirements for conservation of momentum in the ion-cathode collision, the energy being of the order of 5 or 10 eV.

The availability of this relatively large energy in one small packet suggests that a surface atom might absorb the energy and escape. The necessary condition for such a process is that the phonon energy should exceed the binding energy of a surface atom. The process of ion ejection of surface atoms is usually called sputtering. In general, sputtering studies[4] deal with ion energies many times the surface-atom binding energy. However, in the energy range considered in this study, the physical circumstances are quite similar to those involved in the photoelectric emission of electrons, an analogy which suggests the possibility that phonon absorption would be most likely if the phonon energy were slightly above the binding energy of the surface atom, i.e., a condition of resonant absorption. Considering the number of different parameters affecting the phonon energy, it would take a most fortuitous set of circumstances to allow such a resonant phenomenon to take place. Important parameters include the cathode-fall energy, the ion mass, and the crystal structure of the cathode.

Proof that resonant sputtering is responsible for the anomalous cathode erosion is lacking, but there is some experimental confirmation[5], which can be summarized as follows:—

(1) Only iron-bearing materials are affected, and no other property, except the predominance of iron, appears to be significant. This is related to sputtering in that both the energy of the collision-created phonon and the binding energy of the ion are characteristics of the crystal.

(2) The observed exponential growth of erosion would result because material already removed would be captured in the discharge, ionized, and directed back at the surface.

(3) In a sputtering mechanism, the erosion should be rather sensitive to the mass of the bombarding ions. Although many ions are of cathode origin, other ions are derived from the anode and the dielectric; in fact, initially all ions are from the dielectric. As the anode material is vaporized and ionized in the discharge column, "anode" atoms displace the dielectric atoms. Ionized anode atoms, in turn, will be partially displaced by the cathode atoms as more and more of these are sputtered into the discharge column.

Examination of the relationship of iron-cathode erosion to anode atomic weight has revealed that the values of A and α in eq. (1) are both functions of the anode atomic weight, A decreasing with increasing atomic mass from carbon to molybdenum and then increasing again slightly for tungsten, while α increases with increasing atomic weight from carbon to molybdenum and then decreases again for tungsten.

In the present model, the cold cathode is bombarded by ions from the dielectric and the anode. If either or both of these ions produce phonons whose energy lies within the narrow resonant absorption peak, a large number of atoms can be sputtered. Thus, the initial value from which the exponential growth begins is determined by the anode and dielectric atoms. As the cathode atoms become the major source of ions, the erosion rate would be determined by two factors, i.e., the sputtering efficiency of the cathode ions, which is independent of the rest of the parameters of the system, and the sputtering efficiency of the anode atoms on the hot cathode. This latter number should differ from the efficiency on a cold cathode since the hot cathode atoms have less average binding energy. Thus, an ion whose mass was perfect for resonant sputtering on a cold cathode would become much less efficient as the cathode warmed up. The partial pressure of anode atoms is still a significant portion of the pressure in the discharge column, so that their relative efficiency for sputtering hot cathode material will partially determine the rate of exponential growth of cathode erosion. The rule with iron cathodes seems to be that light atoms (with an atomic weight of about 12) are efficient sputtering agents for cold iron, while heavy atoms (atomic weight 100) are efficient sputtering agents for hot iron.

In terms of eq. (1), this model predicts that the dielectric and the anode will determine the value of A, and that the anode (and the cathode, which is not really a variable) will determine the value of α. To test this hypothesis, the normal dielectric, kerosene, was replaced by the more carbonaceous dielectric fluid, alpha-methylnaphthalene. It was reasoned *a priori* that the increase in the number of carbon atoms from the dielectric would increase the value of A but leave that of α relatively unchanged.

The test was run with brass anodes and the standard tool-steel cathodes used with all the other anode tests. The results were almost precisely as predicted, the value of A being more than doubled, while that of α increased

(Concluded on page 88)

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Tests on Cross-Flow Heat Exchangers with Tubes of Different Shapes

(Concluded from November issue)

By H. BRAUER

From *Mitteilungen der Vereinigung der Grosskesselbesitzer (VGB)*, Germany, No. 73, August 1961, pp. 260-276, 30 illustrations.

Test Results

In addition to measurements, photographs of flow patterns were taken. For this purpose, the air flow was replaced by a flow of water, with aluminium powder spread over its surface, the water being circulated in a closed circuit.

These photographs showed that the circular-tube heat exchangers Nos. 1 and 2, with their longitudinally staggered rows of tubes had flow patterns consisting of parallel streams between the lines formed by the consecutive tubes, without transverse deflection of the flow paths. These exchangers are therefore equivalent as regards flow pattern to an arrangement with non-staggered tubes. As previously stated, the size of the vortex region is limited by the tube spacing. With close spacings, the vortex becomes weaker; with very small spacings, stagnation zones are formed, in which the heat transfer is very poor. Consequently, in order to avoid a deterioration in heat-exchanger performance, the tube spacing should not be less than a critical minimum value.

Heat exchanger No. 3, with its rows of circular tubes staggered in the transverse direction (Fig. 4), gave flow patterns showing periodic deflections of the flow paths and mixing of the fluid transverse to the direction of flow. Heat exchanger No. 4, with its arrangement of smooth profiled tubes (Fig. 8), showed laminar flow patterns with well-defined separate channels and periodic changes of direction. Heat exchanger No. 8, with its arrangement of rows of finned tubes alternating with rows of circular tubes (Fig. 10), produced flow patterns with parallel paths of fluid, bounded on both sides by regions with intense vortex formation.

Heat exchanger No. 27, with its arrangement of oval tubes having their minor axis in the direction of flow (Fig. 11a) showed marked deflections of the flow paths and intensive vortices everywhere in the flow. By contrast, heat exchangers Nos. 28, 30 and 31, with oval tubes presenting their major axis to the flow (Fig. 11b), had a flow pattern practically free from vortices (except after the last row), and almost the entire surface of the tubes was in contact with the flow.

TABLE III: NUMERICAL VALUES OF CONSTANTS C AND m

Heat Exchanger No.	C	m
1	0·422	0·61
2	0·190	0·66
3	0·209	0·66
4	0·220	0·64
5	0·176	0·64
6	0·220	0·64
7	0·220	0·64
8	0·109	0·70
27	0·177	0·67
28	0·133	0·67
29	0·381	0·58
30	0·133	0·67
31	0·133	0·67

All the test results now presented are expressed in terms of coefficients of specific resistance ψ (eq. (7)) or of Nusselt numbers as functions of Reynolds numbers. It should be borne in mind that ψ does not include terms associated with the geometrical arrangement of the tubes, so that the values obtained are valid only for the relative longitudinal and transverse spacings s_L/d_o and s_T/d_o given in Table I. The ψ-values, however, are of considerable importance, since they give the results in a form which is applicable to any flow media.

Heat transfer can be expressed in terms of the relation.

$$Nu/Pr^{\frac{1}{3}} = CRe^{m} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

where C and m are constants determined from the test results. For air, $Pr = 0{\cdot}71$. Numerical values of the constants C and m for all the heat exchangers investigated are given in Table III.

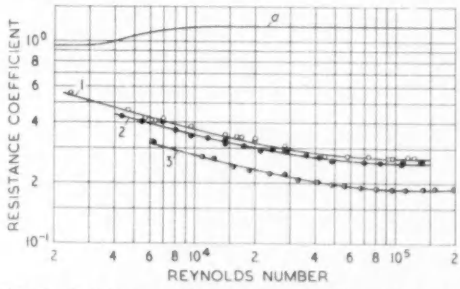

Fig. 14. Resistance coefficient ψ as a function of Reynolds number Re for heat exchangers Nos. 1, 2, and 3, compared with a single isolated tube (a).

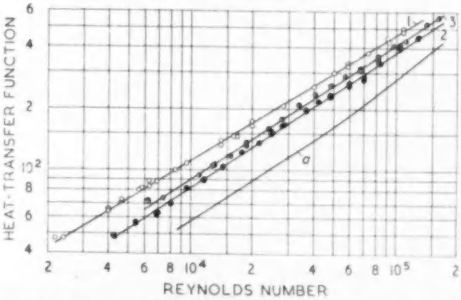

Fig. 15. Heat-transfer function $Nu/Pr^{\frac{1}{3}}$ as a function of Reynolds number Re for heat exchangers Nos. 1, 2, and 3, compared with a single isolated tube (a).

The results obtained as regards heat transfer apply only to the particular values of s_L/d_o and s_T/d_o of the tube arrangements. Figs. 14 and 15 show respectively the resistance coefficient ψ and the heat-transfer function $Nu/Pr^{\frac{1}{3}}$ for circular-tube heat exchangers as functions of Reynolds numbers ranging from 2000 to 200,000, with air-flow velocities from about 1·2 to 60 m/sec in the

narrowest cross-sections between the tubes. The results in Fig. 14 were obtained partially with isothermal flow and partially with non-isothermal flow, no differences in the values of resistance coefficient ψ being observed under these conditions. The ψ-values for a single tube (curve (*a*) in Fig. 14) are higher than the corresponding values for tube banks, because with banks of tubes the boundary-layer flow along the tube wall changes to a turbulent condition at a much earlier stage, and this restricts the size of the vortex region causing high energy losses. At very low values of Reynolds number, and at a Reynolds number of about 400,000 (when the change to fully turbulent condition takes place), the ψ-values for tube banks should be approximately equal to those of a single tube. However, these extreme regions were outside the range investigated. The smoother trend of the ψ-curves for the tube banks is due mainly to the vortex regions between consecutive tubes, resulting in a higher degree of turbulence of the main flow.

The highest resistance coefficients ψ were obtained with heat exchanger No. 1, which has values of longitudinal spacing s_L about twice as great as those of heat exchanger No. 2. This confirms the fact that ψ increases when the magnitude of the vortex region is increased. Heat exchanger No. 3, with its optimum spacings, gave the lowest ψ-values. In all cases, good agreement was obtained with the results previously published by Grimison[2].

The results of heat-transfer function $Nu/Pr^{\frac{1}{3}}$ as a function of Reynolds number Re for heat exchangers Nos. 1, 2, and 3, plotted in a log-log diagram, as shown in Fig. 15, have a scatter of less than $\pm 3\%$, and are compared with curve (*a*) for a single tube, which is based on results previously obtained by Hilpert[3]. Curve (*a*) gives a Reynolds-number exponent m of 0·615 up to Re = 40,000, and 0·805 from 40,000 to 400,000. This increase in m at very high Reynolds numbers can also be expected for banks of tubes, but up to Re = 200,000 the linear representation gives ample accuracy in practice. Again, the difference between Nusselt numbers for the three heat exchangers can be attributed to the behaviour of boundary layers and the degree of turbulence.

It should be noted that heat exchanger No. 1 gave the best heat transfer and also the highest flow resistance, owing to its greater longitudinal spacing. Good heat transfer and low flow resistance were obtained with heat exchanger No. 3, mainly because of its favourable transverse spacing s_T/d_o, with periodic deflections of the flow. Generally, however, the improvement in heat transfer obtained with a staggered arrangement, in comparison with an in-line arrangement of the rows of tubes, is relatively small.

The heat exchangers with profiled tubes had a lower flow resistance than those with circular tubes, particularly at high Reynolds numbers, as indicated in Fig. 16, in which the curves show a similar trend for all the tubes shapes, though they reach different asymptotic values for different tube shapes and tube arrangements. Confirmation that the resistance coefficient decreases as the number of rows is increased is obtained by comparing the curves for heat exchangers No. 4 (ten rows of tubes) and No. 5 (five rows). According to prevailing opinion, the lowest ψ-value is reached when ten rows of tubes are used. Heat exchanger No. 6 with fluted profiled tubes gave, as expected, a higher flow resistance than No. 5 with its smooth profiled tubes. Both of these heat exchangers have five rows of tubes, so that a comparison seems permissible.

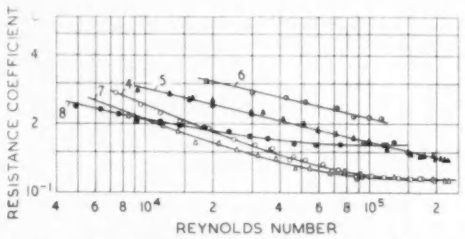

Fig. 16. Resistance coefficient ψ as a function of Reynolds number Re for heat exchangers Nos. 4 to 8

Of the composite arrangements of heat exchangers investigated, the results in Fig. 16 for heat exchanger No. 7, with its alternating rows of profiled tubes and circular tubes, show little difference in comparison with No. 4, which consists entirely of smooth profiled tubes, slight deviations occurring only at low Reynolds numbers. Heat exchanger No. 8, with alternating rows of finned tubes and circular tubes, has much higher values of flow resistance than No. 4 at high Reynolds numbers, but these are still much lower than those of heat exchanger No. 2, which consists solely of circular tubes.

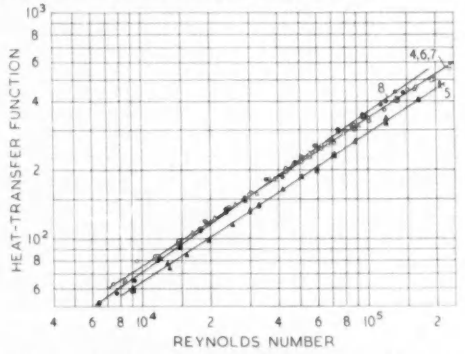

Fig. 17. Heat-transfer function $Nu/Pr^{\frac{1}{3}}$ as a function of Reynolds number Re for heat exchangers Nos. 4 to 8.

The results for heat-exchangers Nos. 4 to 8 as regards heat transfer are plotted in Fig. 17, in which it was possible to draw a common straight line through the test points for heat exchanger Nos. 4, 6, and 7. The line for heat-exchanger No. 8 has a somewhat greater slope, but is not very different from the previous line. A comparison of the heat exchangers with smooth profiled tubes shows that No. 5 (five rows of tubes) gives heat-transfer values about 20% below those of No. 4 (ten rows of tubes). It is known that the heat transfer coefficient h increases with the number of rows of tubes and reaches its final value for about ten rows. It should be noted that, although the equivalent hydraulic diameter d_h was used for calculating Nusselt and Reynolds numbers of heat exchangers Nos. 4 to 7, and the tube outer diameter d_o for No. 8, the h-values were calculated from the true surface areas of the tubes with the aid of eq. (1).

From Figs. 15 and 17, it is found that the heat-transfer coefficient h has about the same value for heat exchangers No. 8 and No. 2, although, in general, h-values decrease when ribs or fins are added to a surface. The remarkable constancy of the value of h in this case is due to the position of the fins in the neighbouring vortex regions.

A further comparison of Figs. 15 and 17 can be made for heat exchangers Nos. 2 and 4, which have very nearly

the same equivalent hydraulic diameter. At a Reynolds number of 10,000, No. 2 has a $Nu/Pr^{\frac{1}{3}}$ value of 83, whereas its value for No. 4 is 76. Consequently, as previously stated, the substitution of profiled tubes for circular tubes in transverse flow has little effect on heat transfer and does not bring about an improvement.

It is immaterial whether the equivalent hydraulic diameter d_h or the equivalent circular-tube diameter d_s is used for such comparisons. For instance, heat exchanger No. 4 has profiled tubes with a d_s-value equal to the outer diameter d_o of the circular tubes of heat exchanger No. 3. At a Reynolds number of 10,000, their $Nu/Pr^{\frac{1}{3}}$ values are 85 and 91 respectively, representing a difference of only 7%.

To sum up, the use of profiled tubes instead of circular tubes does not have a substantial effect on heat transfer, but flow resistance is reduced considerably.

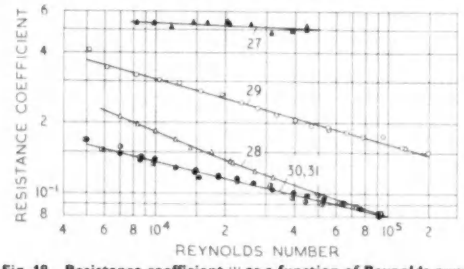

Fig. 18. Resistance coefficient ψ as a function of Reynolds number Re for heat exchangers Nos. 27 to 31.

Heat exchangers Nos. 27 to 31 gave the resistance coefficients plotted in Fig. 18, in which it was again possible to draw straight lines through all the test points for the range of Reynolds numbers investigated. Asymptotic values were not obtained, although some of the tests reached Reynolds numbers of 100,000. Generally, the ψ-values were lower than those of tube banks with circular tubes or profiled tubes.

It was possible to draw a common straight line for heat exchangers Nos. 30 and 31, which have approximately the same relative values of longitudinal and transverse spacings s_L/d_{maj} and s_T/d_{min}, though their tube dimensions are different. The spacing ratios are also nearly the same for heat exchanger No. 28, but in this case the straight line has a greater slope, with higher ψ-values at Reynolds numbers below 100,000. The results indicate that, for oval tubes with the major axis in the direction of the flow, the drag due to the shape factor is less important than frictional resistance. This conclusion applies to any flow media. The evaluations were based on the equivalent hydraulic diameter d_h.

The very close transverse spacing s_T/d_{min} of the tubes is responsible for the high resistance values of heat exchanger No. 29. By comparison, the effect on pressure losses of the longitudinal spacing s_L/d_{maj} is only of minor importance. Heat exchanger No. 27 gave the highest ψ-values, owing to its tube arrangement with the minor axis in the direction of the flow. The effect of the shape factor, with flow parallel to the minor axis, is in this case preponderant, and frictional resistance is of secondary importance. This is why the ψ-line is nearly horizontal, with a mean value of 0·53.

Fig. 19 shows the heat-transfer relationships for heat exchangers Nos. 27 to 31. A common straight line can be drawn through the test points of heat exchangers Nos. 28, 30, and 31, which have similar features.

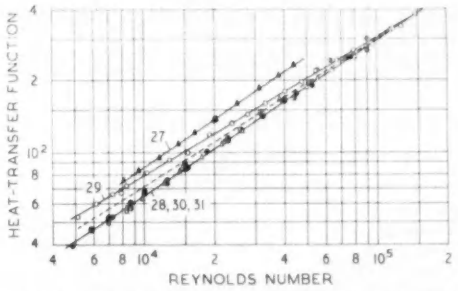

Fig. 19. Heat-transfer function $Nu/Pr^{\frac{1}{3}}$ as a function of Reynolds number Re for heat exchangers Nos. 27 to 31.

Separate lines represent the results with heat exchangers Nos. 27 and 29, which have considerably different tube arrangements. These tube arrangements were chosen as extreme cases but, even in the lower range of Reynolds numbers, the differences are only about 25%. It can therefore be inferred that, with oval tubes, the tube arrangement has no appreciable effect on heat transfer. The dotted line in Fig. 19 gives the mean values for all oval tubes with their major axis in the direction of the flow, the analytical expression for this dotted line being

$$Nu = 0{\cdot}236\ Re^{0{\cdot}62}Pr^{\frac{1}{3}} \quad .. \quad .. \quad .. \quad (9)$$

with Reynolds numbers based on equivalent hydraulic diameter d_h.

It has already been noted in connection with flow-pattern recordings that the flow around oval tubes is not appreciably altered when they are arranged in the form of banks. It can therefore be expected that their specific heat transfer will be approximately the same as for a single oval tube. Measurements by Knoblauch and Reiher[4] on the heat transfer of a single oval tube in a transverse flow for Reynolds numbers from 2500 to 15,000 gave the relationship

$$Nu = 0{\cdot}251\ Re^{0{\cdot}612}Pr^{\frac{1}{3}} \quad .. \quad .. \quad .. \quad (10)$$

where both the Nusselt and Reynolds numbers are based on the equivalent circular-tube diameter d_s. Eq. (9) can be converted to values based on the equivalent circular-tube diameter d_s by multiplying its numerical constants by the ratio d_s/d_h. It then becomes

$$Nu = 0{\cdot}254\ Re^{0{\cdot}62}Pr^{\frac{1}{3}} \quad .. \quad .. \quad .. \quad (11)$$

which is in very good agreement with eq. (10). The difference between single tubes and banks of tubes is only 7% for oval tubes. For circular tubes, the heat transfer of a tube bank is from 40 to 50% higher than that of a single tube. Heat exchanger No. 27, with flow in the direction of the minor axis of the tube, shows the highest heat-transfer values, but also has very high flow resistances, and is therefore not recommended. The heat-transfer values for heat exchanger No. 27 agree extensively with those obtained by Knoblauch and Reiher[4] for a single oval tube with flow in the direction of the minor axis.

Considering in each case the most favourable tube arrangements, it therefore appears that heat exchangers with oval tubes are preferable to those with circular or profiled tubes, because banks of oval tubes have a considerably lower flow resistance and good heat transfer. The differences in heat-transfer values for optimum tube arrangements are, however, fairly small, the deviations in some cases being within the limits of

accuracy of the tests. With a Reynolds number of 10,000, for instance, typical values of $Nu/Pr^{\frac{1}{3}}$ are 83 for heat exchanger No. 2, 91 for heat exchanger No. 3, 85 for heat exchanger No. 4, and 78 for exchangers Nos. 28 to 30.

Comparative Assessment of Heat Exchangers

The operating economy of a heat exchanger depends on eqs. (1) and (2), which determine the heat flow Q transferred and the power P required by pumps or blowers. Thus, the coefficient of flow resistance ψ and the Nusselt number Nu are only two of the quantities to be considered and are not sufficient by themselves for a complete assessment.

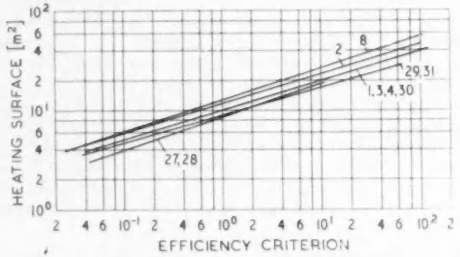

Fig. 20. Heating surface A_1 as a function of efficiency criterion ε, for the heat exchangers investigated.

Two heat exchangers can be regarded as equivalent, on an energy basis, if they give the same value for the ratio Q/P. Following a procedure suggested by Glaser[5], Q can be replaced by Q_1, so that

$$Q_1 = hA = Q/\triangle T \quad .. \quad .. \quad .. \quad (12)$$

Thus, Q_1 is the heat-flow rate for a temperature difference $\triangle T$ of 1°C. The ratio Q_1/P can then be introduced as the efficient criterion ε_1 of the heat exchanger, i.e.,

$$\varepsilon_1 = Q_1/P \quad .. \quad .. \quad .. \quad .. \quad (13)$$

A high value of ε_1 indicates a high heat transfer per unit power for pumps or blowers.

For compact heat-exchanger design, the endeavour is to make the heating surface A and the exchanger volume V as small as possible. For tube banks in a transverse flow, the unit volume V_1 to be considered is

$$V_1 = s_T s_L L \quad .. \quad .. \quad .. \quad .. \quad (14)$$

where L is the tube length. The heating surface A_1 of one tube is Ls, where s is the tube perimeter, so that A_1 can be substituted in eq. (14), which then becomes

$$V_1 = s_T s_L A_1/s \quad .. \quad .. \quad .. \quad .. \quad (15)$$

It is convenient to evaluate the required heating surface A_1 from the relation $A_1 = Q/h\triangle T$, where $Q = 1000$ kcal/hr, $\triangle T = 1$°C, and h is the heat-transfer coefficient in kcal/m²-hr-°C. It then follows that V_1 is the volume of the heat exchanger required to transfer 1000 kcal/hr at $\triangle T = 1$°C.

Both A_1 and V_1 are associated with corresponding values of the efficiency criterion ε_1, and it is therefore possible to assess the comparative effectiveness of various heat exchangers by considering diagrams of A_1 and V_1 plotted as functions of the efficiency criterion ε_1.

The relationship between the required heating surface A_1 and the efficiency criterion ε_1 for the heat exchangers investigated is shown in Fig. 20, in which the test points have been omitted to simplify the diagram. It can be seen that heat exchangers Nos. 27 to 31 with oval tubes have the lowest requirements as regards heating surface, and are therefore favourable designs. Heat exchanger No. 4, with smooth profiled tubes, is in this respect equivalent to the circular-tube heat exchangers Nos. 1 and 3. Heat exchanger No. 8 with finned tubes requires the largest heating surface and is therefore the least favourable.

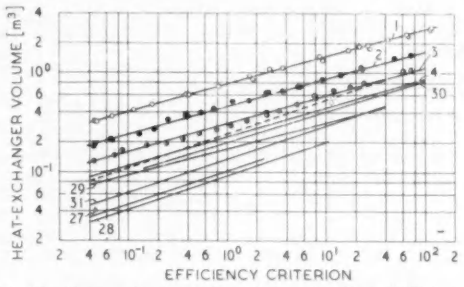

Fig. 21. Heat-exchanger volume V_1 as a function of efficiency criterion ε, for the heat exchangers investigated.

The unit volume V_1 required is indicated in Fig. 21, in which there was sufficient space between the lines in this diagram to include the test points for the heat exchangers Nos. 1, 2, and 3 with circular tubes. The diagram shows very clearly the advantage of the oval tubes for heat exchangers with regard to minimum volume. This advantage also has a favourable effect on the associated costs of the boilers and containers required.

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Anomalous Cathode Erosion with Arcs of Millisecond Range during Spark-Machining

(*Concluded from page 84*)

slightly. This increase in α might be attributable to an increase in the ratio of steel to brass ions as the result of the larger value of A. Steel anodes gave a significantly larger value of α than brass, whose low melting point makes it a less satisfactory anode than, for example, copper.

There remains the matter of an explanation of the observed knee in Fig. 1. This can be accounted for by a possible thermal time lag. An estimate of the time it would take to raise the temperature of a hemisphere of steel with a cross-section equal to the arc-column diameter to the boiling point from room temperature gives a value of a few milliseconds with an arc current of 100 A. The presence of "boiled" material would interfere with the ions reaching the cathode, acting as an ion mirror. This is in accordance with Von Engel's model[2].

Another possibility is that a less drastic change of state, such as a change in the crystal arrangement or the liquefaction of the metal under the discharge column, would reduce the sputtering rate rather drastically.

Carbide Precipitation in Cobalt-Base Heat-Resistant Alloys during Age-Hardening

By B. LUX and W. BOLLMANN

From *Cobalt*, Belgium,
No. 12, September 1961,
pp. 32–38, 18 illustrations.

THE strengthening mechanism of most heat-resistant cobalt-rich alloys is based on precipitation-hardening with complex carbides. These alloys, which have a very high creep resistance, are often used in the as-cast condition because of their poor formability. To confer full strength on these alloys, they are subjected to an age-hardening treatment, which is carried out on the as-cast alloys or after a solution heat treatment, and it is the object of this article to present some observations on the carbide precipitation in cobalt-base alloys during ageing.

The basic material used in this investigation was the cobalt-rich heat-resistant alloy HE 1049, which contains 0·4% carbon, 26% chromium, 15% tungsten, 10% nickel, 0·4% boron, 0·8% silicon, and 0·8% manganese. However, to clarify the dominant processes involved, most of the work was carried out with a simplified alloy of cobalt, containing 0·4% carbon, 27·5% chromium, 16% tungsten, and 11·6% nickel.

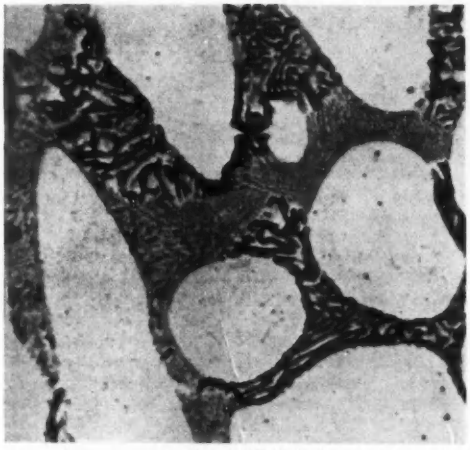

Fig. 1. Microstructure of cast HE 1049 alloy, creep-tested at 900° C, showing eutectic carbides. (Etchant : $Na_2Cr_2O_7$/ $KMnO_4$) (×500)

The microstructure of the cast HE 1049 alloy showed the presence of many carbides, located between primary dendrites, this structure resulting from a eutectic solidification. Fig. 1 illustrates the microstructure of this cast alloy, creep-tested at 900°C, and shows these eutectic carbides. The solidification curve of the alloy, in terms of temperature as a function of time, is shown in Fig. 2, in which one of the two arrests corresponds to the beginning of solidification of the primary dendrites, and the other to freezing of the eutectic. In Fig. 3, an attempt has been made to represent the solidification behaviour of this complex alloy in a quasi-binary diagrammatic form.

In order to determine the nature of the carbides present in the commercial alloy HE 1049, as cast, the carbides were extracted by electrolytic attack with alcoholic hydrochloric acid. In the X-ray diffraction patterns of the residues obtained, only one phase, with a lattice parameter $a = 10{\cdot}78\ kx$, was detected. The pattern matches that reported by Goldschmidt for a composition of the type Me_4W_2C-Me_6W_6C. In the precipitate of alloy HE 1049, nickel is probably partially substituted for cobalt and it can be expected that tungsten is replaced partially by chromium, and carbon partially by boron and silicon.

For investigating changes in microstructure during ageing, the simplified alloy was used. The precipitate present in this alloy proved to be almost identical in crystal structure with that in alloy HE 1049. The microstructure of the simplified alloy showed the presence of small precipitated particles growing in the vicinity of the eutectic carbides during age-hardening of the as-cast alloy. These precipitates surround the eutectic carbides in a cloud-like formation, as shown in Fig. 4, and have the shape of branched plates and needles (Fig. 5).

The centre of a eutectic carbide is shown in Fig. 6, in which, besides dark spots of carbide, areas with very fine precipitation and regions showing no precipitation are visible. The fine precipitation in the austenitic regions of the eutectic may be explained by the fact that the

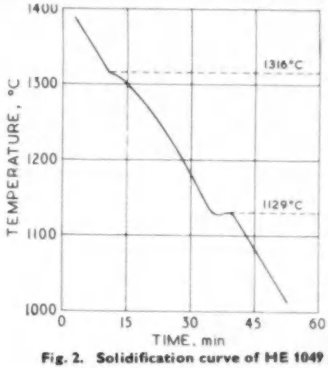

Fig. 2. Solidification curve of HE 1049 alloy.

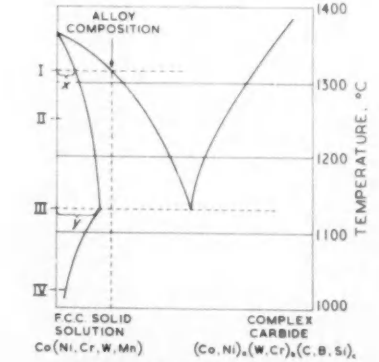

Fig. 3. Quasi-binary equilibrium diagram illustrating the solidification behaviour of HE 1049 alloy.

Fig. 4. Cloud-line formation of precipitates around eutectic carbides in the simplified cobalt alloy. (×30,000)

Fig. 5. Individual precipitates in the simplified cobalt alloy, showing their branched-plate and needle form. (×60,000)

eutectic is composed of alternate regions of carbides and austenite. This austenite is strongly supersaturated with respect to carbon at the ageing temperature, so that a precipitation of very fine carbide particles takes place during age-hardening. The light, more homogeneous spots in Fig. 6 may represent a third phase, which has not been identified, but which might be a second chromium carbide phase.

Solution heat-treated specimens showed quite a different structure after ageing. During heat treatment at 1250°C (when the eutectic can be expected to be liquid), the eutectic carbides agglomerated into drop-like shapes. In aged specimens, fine precipitated particles were uniformly distributed over the whole of the austenitic grains.

These phenomena may be explained by means of Fig. 3, from which it is expected that the later these zones solidify, the more will the concentration of carbon in different zones of the matrix increase. The surrounding of the eutectic, which is the last zone of the matrix to solidify, will thus contain the highest carbon concentration outside the eutectic. After ageing at 800°C, the highest concentration of precipitates is found in the region where the matrix is most supersaturated with respect to carbon, i.e., the zones adjoining the eutectic. Furthermore, diffusion of carbon out of the eutectic during age-hardening may occur, since the mean carbon concentration of the matrix is lower than that corresponding to equilibrium at the eutectic temperature. Consequently, on age-hardening, this diffusion would help to increase the density of the precipitates around the eutectic.

During solution heat-treatment, the carbon segregation resulting from the solidification is eliminated, so that subsequent ageing forms precipitated particles which are homogeneously distributed throughout the austenite grains. Electron diffraction patterns show that the carbide particles precipitated during an age-hardening heat treatment are coherent with the face-centred cubic matrix, form on the (100) planes, and grow in the [110] directions of this matrix.

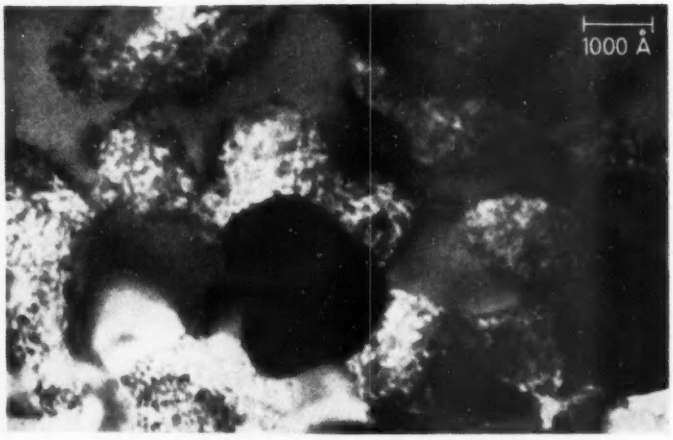

Fig. 6. Centre of a eutectic carbide in the simplified cobalt alloy. (× 100,000)

The Causes and Prevention of Corrosion of Stainless Steel

By M. SINCLAIRE and E. PHILLIPS

From *Metal Progress*, U.S.A.,
Vol. 80, No. 3, September 1961,
pp. 92-96, 6 illustrations.

MANY fabricators and users of stainless steel have often discovered that these steels are not always stainless in all kinds of environments, but are merely corrosion-resistant. The corrosion which occurs is apparently inexplicable, usually unexpected, and sometimes leads to catastrophic consequences. For the successful application of this series of alloys, an understanding of the basic mechanism by which they corrode and resist corrosion is essential. This article is therefore concerned with the main causes of corrosion of stainless steels and the preventive measures that should be taken.

Sensitization

Perhaps the most commonly recognized phenomenon is intergranular corrosion resulting from sensitization. Occurring principally in austenitic stainless steels when they are heated in the range from 900 to 1400°F, sensitization leads to precipitated chromium carbides at the grain boundaries, chromium depletion in zones adjacent to these grain boundaries, and a difference in solution potential between the centre of the grains and their outer chromium-depleted zones. It can be minimized by limiting the amount of carbon or by adding a stabilizing element such as titanium, columbium, or tantalum, which have a higher affinity for carbon than has chromium, and their carbides are therefore preferentially precipitated. If parts are to be used in the sensitizing range, they must be made from stabilized grades.

However, even stabilizing elements do not prevent sensitization under all conditions. For example, in a carburizing environment, the carbon content of the steel may be raised beyond the capability of the stabilizer. The carburized surface is then subject to the same chromium carbide precipitation as an unstabilized steel.

It should be recognized that carburization can occur as a result of discrepancies in fabrication, as well as service conditions. To avoid carburization, stainless steels should be kept away from any carburizing atmospheres such as natural gas, carbonaceous furnace atmospheres, or rich oxyacetylene flames, and must be free from all grease and carbonaceous soil before heating. Marking devices such as graphite pencils and wax crayons, which leave a heavy deposit of carbon on the surface, must not be used.

Entrapped Corrodents

At times, fabricators of stainless steel sow the seeds of corrosion problems by unknowingly entrapping potential corrodents in their assemblies. Generally, the corrosion which occurs results from decomposition of a chlorine-containing material.

The most common of these materials is trichlorethylene, a valuable degreasing agent. Although it is one of the most stable of halogenated hydrocarbons, it slowly liberates hydrochloric acid when contaminated with water. The reaction is catalysed by iron, and its rate increases as temperature rises. Corrosion products seem to accentuate the catalysis and cumulatively accelerate the reaction. Although a "stabilizing" agent is incorporated in degreasing grades of trichlorethylene, it merely reduces potential corrosion problems by reacting with any acid liberated. Obviously, the introduction of abnormal amounts of water into the solvent produces more acid than can be neutralized by the stabilizer. Sometimes, the water-trichlorethylene mixture is formed on the condenser pipes of vapour-degreasing equipment during hot, humid weather. More often, it results from dipping parts or assemblies in an aqueous medium either before or after degreasing. A simple baking operation (30 min at 190°F) after degreasing can often solve this problem. Other materials to which corrosion problems have been attributed include vinyl chloride plastics, chlorinated lubricants, and plastics catalysed with hydrochloric acid.

If the processing of a stainless-steel part is carefully controlled, so that its microstructure is faultless and entrapped corrosive agents have been avoided, then its freedom from corrosion during service will depend on its configuration and environment. The first of these two factors is solely the responsibility of the designer, who must recognize that stainless steels are not a panacea for corrosion problems. To achieve corrosion resistance in all stainless-steel parts, the designer must be cognizant of the mechanisms by which corrosion may be initiated.

The high resistance to corrosion exhibited by stainless steel is due to its ability to form a thin, but tight, submicroscopic oxide film on its surface, i.e., the so-called "passive film". Without this film, the corrosion resistance of stainless-steel alloys would not be much better than that of ordinary carbon steel. Stainless steel possessing this film is said to be "passive"; lacking this film it is referred to as "active".

The composition and thickness of the oxide film are variable, depending on the heat treatment, surface preparation, and composition of the alloy. Normally, it consists mainly of chromium oxide with a small quantity of iron oxide and a trace of nickel oxide. The greater the chromium oxide content of the passive film, the more protection it will afford. Stainless steel will form a passive film on its surface in air or other oxidizing media, such as water which contains dissolved oxygen, and of course in a nitric acid solution (the well-known passivating bath). In a sense, the film actually represents corrosion of the stainless steel but, because it is so thin, tightly adherent, insoluble, and somewhat impervious to most liquids, gases, and ions, it protects the underlying metal from continued oxidation or corrosion.

As might be expected, the passive film alters the electrochemical behaviour, or solution potential, of the underlying metal because it interferes with the flow of ionic traffic to and from the metal. Thus, in a saline solution, it acts as a retarding screen to the migration of chloride ions to, and ferrous ions from, the metal surface. The net effect of this behaviour is to make the passivated stainless steel more cathodic or more noble than an active alloy. The difference in potential between passive and active stainless steel is reported to be between 0·5 and 0·6 V, a significant difference in corrosive activity. If the passive film is interrupted or partly removed, an

electrolytic cell will be formed between the active (anodic) and the passive (cathodic) areas when an electrolyte is present, and corrosion will occur. It follows, then, that both design and maintenance must be aimed at maintaining the integrity of the passive film.

Crevices and Recesses

It has been pointed out that the passive film does not form a completely impenetrable barrier, as it impedes, but does not completely stop, the flow of ions and electrons. Thus, corrosion can be initiated through the passive film on the metal beneath. When this occurs, the integrity of the passive film in the corroded area is completely destroyed and the area becomes active.

One of the common mechanisms which initiates the corrosion of stainless steel is the formation of any oxygen-concentration cell, resulting from localized oxygen starvation such as that occurring beneath a covered area of a stainless-steel surface. Corrosion resulting from this source is referred to as "contact corrosion" or sometimes as "crevice corrosion". Oxygen from the air will dissolve readily in an electrolyte exposed to air; however, an electrolyte trapped between two contacting surfaces is almost completely shut off from a source of oxygen. This area is then forced to become anodic to the surrounding uncovered, high-oxygen area, which becomes an oxygen cathode. Corrosion occurs at the anode (covered) area, the corrosion products destroy the passive film, and an active area results. The potential difference between this active area and the surrounding inactive area creates a destructive corrosion cell. It is fairly obvious that folds, seams, or recesses in stainless-steel parts will be particularly vulnerable to this type of attack. Similarly, but perhaps not so obviously, crevices formed by washers, tunnels formed by overlapping of labels, improperly applied labels, or poultices of encrusted dirt will also create corrosion sites.

Surface Contaminants

Pitting is the usual form of attack experienced by stainless steel in marine and industrial atmospheres. Although the actual quantity of metal lost as a result of pitting is usually slight, it can spoil appearance and, in certain instances where pit growth continues to the point of complete or even near-complete perforation, the consequences can be serious.

For example, several failures (pin-hole leaks) in stainless-steel hydraulic lines taken from naval aircraft based aboard aircraft carriers were investigated. Originally blamed on fatigue, these failures were actually caused by corrosion. It was found that pitting occurred on the top and bottom quadrants of horizontal portions of lines in areas normally open to the atmosphere. These lines were always found to be covered with dirt particles composed mainly of sand, sodium chloride, and iron oxide. Microchemical tests also disclosed the presence of chloride ions within the pits. The same pitting damage was reproduced in the laboratory on a section of new, sound tubing by sprinkling it with sand or powdered iron and placing it in a humid, saline environment. Both of these contaminants initiated minute active areas which subsequently became pits.

The mechanism of this kind of corrosion begins with the formation of an oxygen-starved area under a particle of dirt, the corrosion products found in the pit mainly being ferrous and ferric chlorides. These products hydrolyse in water, yielding a significant quantity of hydrogen ions and, of course, chloride ions. Both chloride and hydrogen ions are effective depassivators, preventing the surface of the pit from repassivating. A typical pit in stainless steel is actually a tiny anode (active site) surrounded by (and electrically coupled to) a relatively enormous cathode (passive area). Because of the high anode current density, pit depth can increase rapidly if enough moisture and chloride ions are present.

Metal Particles

Steel or iron dust contaminating a stainless-steel surface will create an active site even more readily than sand. Unfortunately, this type of contamination is very common in airborne dust in urban and industrial areas. When an iron or steel particle resting on a stainless-steel surface becomes covered by a film of moisure, it rusts rapidly, since it is anodic to stainless steel. The corrosion products of the steel particle will depassivate the stainless steel on which they are deposited, creating an active site and a subsequent pit.

In marine environments, salt crystals can also initiate active sites. They provide a good electrolyte under humid conditions and, since the metal beneath the crystal is deprived of oxygen, pitting proceeds by typical contact phenomena.

To avoid corrosion originated by metallic dust, sand, and salt, the surface must be kept clean. Soap or detergent will generally remove this type of contamination. Rubbing with a dry cloth is not advisable, since it may scratch polished surfaces and damage the passive film. If the particles cannot be removed by washing, indicating that pitting has already started (particles are "glued" to the surface by corrosion products), a non-scratching polishing preparation should be used to restore the integrity of the surface. If regular maintenance is not practical or possible, the surface may be coated with a protective compound or painted, if a bright polished finish is not needed.

One of the common sources of premature corrosion of stainless steel is acquired during fabrication in the form of metallic contaminants transferred from a dull cutting tool or embedded into the surface during grinding, tumbling, polishing, sand- or shot-blasting, and drawing or forming. This type of contamination can usually be removed in a passivating bath, and this is one of the important benefits of passivation. Electropolishing of the stainless-steel surface is a very effective means of removing material transferred to it from cutting tools, the smooth finish also helping to increase corrosion resistance. Ammonium citrate or other mild pickling solutions have been used to remove metal pick-up, particularly where contamination is heavy.

Conclusion

To summarize the various expedients available for preventing the corrosion of stainless steel, it can be stated that, in the case of unstabilized stainless steel, processing and operating temperatures should be kept below 800°F. In general, stainless-steel parts should be passivated, and carburization should be avoided. In addition, all surfaces should be kept clean, configurations likely to trap moisture should not be used, manufacturing debris, fluxes, tool and die pick-up, and all traces of chlorinated degreasing solvents should be removed, and materials evolving hydrochloric acid eliminated.

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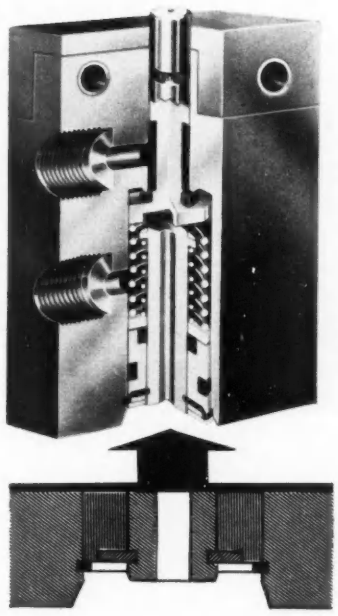

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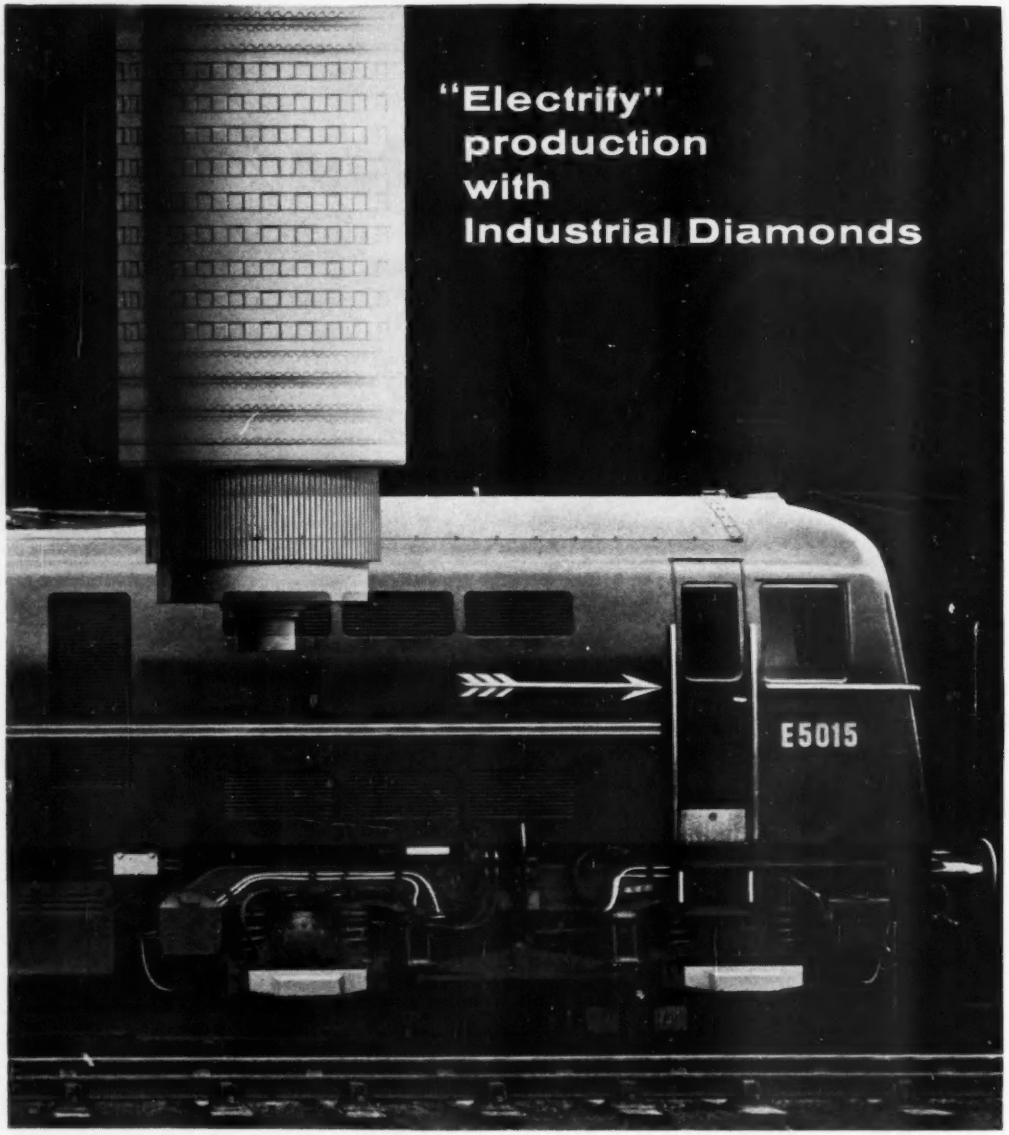

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British Industrial Developments

Automatic Plating Plant for Motor-Cycle Wheel Rims

A new type of plating plant, the only one of its kind in the U.K., has recently been installed at the Coventry works of Triumph Engineering Ltd. for the nickel and chromium plating of Triumph motor-cycle wheel rims, though other items, such as kick-start levers, brake levers, and silencers, can also be catered for. Designed and manufactured by W. Canning & Co. Ltd., of Birmingham 18, this plant is a special "Trojan" hydraulic return-type unit with an output of 48 rims per hour, and its introduction is stated to have enabled Triumph to increase considerably their output of wheel rims and, at the same time, to ensure a standard of finish to a degree of uniformity never before achieved. In fact, on a production basis of 40,000 rims, the reject figure is reported to be less than 0·1%.

The "Trojan" plant supersedes manually operated equipment and is housed in a new two-storey building, the rectifiers, pumps, compressed-air equipment, and other ancillary plant being on the ground floor, whilst the actual plating plant is on the floor above, thus allowing more operational room. The plating plant, which is 47 ft in length, 13 ft in width, and 12 ft in height, is basically in two sections, the first section comprising the cleaning and chromium-plating tanks and swills, and the other section made up of specially designed nickel-plating tanks. Work is transferred between the two sections by means of a solenoid-operated pick-up pawl and carried to a vacant nickel station by a pusher

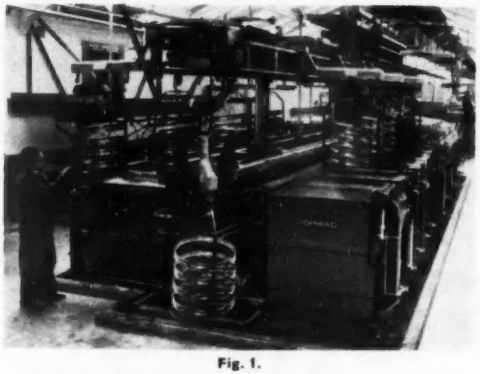


Fig. 1.

fitted to an overhead transfer chain. An indexing switch determines the loading sequence of the nickel stations, energizing a solenoid-operated lifting and lowering pawl at the empty position. The loaded jigs are first passed through a hot-soak cleaner, followed by a cold swill, and then to a hot electrolytic cleaner, followed by two cold swills. They are then subjected to an acid-etch process and two cold swills, after which they are bright nickel-plated and subjected to two more cold swills. The next step involves chromium-plating, drag-out, and neutralizing operations, followed by two cold swills and a hot swill, after which the jigs are unloaded. Loading and unloading of the plating jigs are effected by only one operator, and the work arms are provided with additional hooks, so that standard-type plating jigs can be used in place of those for rims. Part of the plant is illustrated in Fig. 1, which shows (left) a jig of rims being loaded at the cleaning end, and jigs of chromium-plated rims (right) passing through the final rinsing stages.

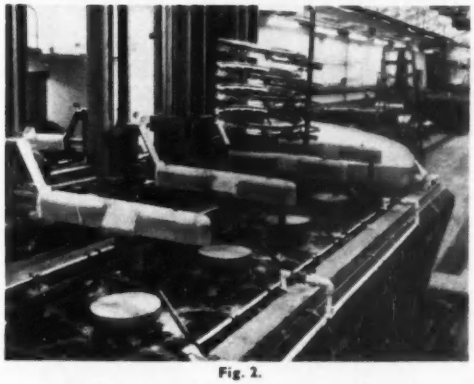


Fig. 2.

A special feature of the plant is that it employs the multiple-cell plating principle, in which, instead of progressing through the bright nickel-plating tank, the work is set down in one of eight different sections or cells, with the rims held horizontally in the jig and surrounding a fixed central core of nickel anodes. Fig. 2 shows four jigs of rims in the nickel-plating cells, each with a central core of anodes.

During the acid-etch process, the work is immersed for 2½ min but, by means of a timing device, the rectifier is switched on for only the final 45 sec. In this way, an evenly etched surface, without any pickling effect, is achieved before the voltage is applied. The system of rinses employed after most processes is of the counterflow type and is a distinct advantage, insofar as saving water and producing a much cleaner final rinse are concerned.

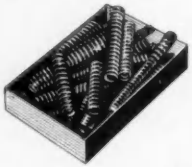
It is stated that appreciable economy in nickel consumption has resulted from the new method of plating. Thus, with the old method, the rims had to be "overplated" by as much as four times the estimated processing time to ensure that the spoke band, which usually attracts the least nickel, received a sufficient thickness, whereas the rim beads attracted four times as much nickel as the spoke band. With the new process, this ratio has been substantially reduced and, apart from the economy effected in nickel consumption, it is stated that the ductility and adhesion of the deposits have also been improved.

Data-Acquisition Equipment for Life-Testing Transistors

Specially designed by the Electronics Division of Microcell Ltd., a subsidiary of BTR Industries Ltd., automatic data-acquisition equipment has been installed in the new semiconductor plant of Texas Instruments Limited, of Manton Lane, Bedford, to record the results of parameter measurements made on 2000 transistors

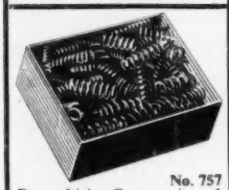
EXPERIMENTAL SPRINGS?

No. 1200
Three dozen Assorted Light Expansion Springs, suitable for carburettor control, etc. **15/-.**

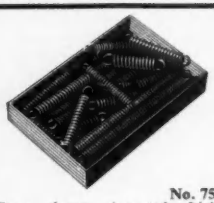


No. 760
Three dozen Assorted Light Compression Springs. 1" to 4" long, 22 to 18 S.W.G., $\frac{1}{4}$" to $\frac{1}{2}$" diam. **7/6.**

No. 98A
Three dozen Assorted 1" to 4" long, $\frac{1}{2}$" to $\frac{3}{8}$" diam., 19G to 15G. **6/6.**



No. 757
Extra Light Compression, 1 gross Assorted, $\frac{1}{4}$" to $\frac{1}{2}$" diam., $\frac{1}{2}$" to 2$\frac{1}{2}$" long, 27 to 19 S.W.G. **18/-.**



No. 753
Three dozen Assorted Light Expansion $\frac{1}{2}$" to $\frac{1}{4}$" diam., 2" to 6" long, 22 to 18 S.W.G. **12/-.**

No. 758
Fine Expansion Springs. 1 gross Assorted $\frac{1}{2}$" to $\frac{1}{8}$" diam., $\frac{1}{2}$" to 2" long, 27 to 20 S.W.G. **18/-.**

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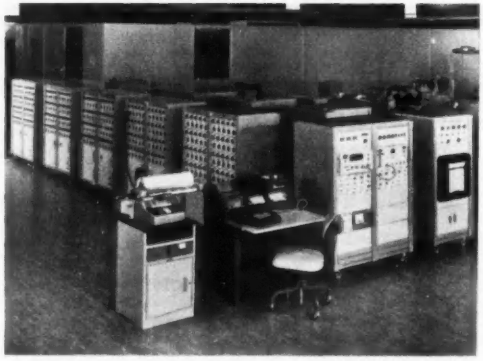
undergoing extended life tests. For economic reasons, a compromise has had to be reached between completely automatic and completely manual operation of the equipment; for this reason, the arrangement finally adopted involves manual selection of the device to be tested, parameter circuit configuration, measurement, and recording being automatic.

The 2000 transistors are housed in five controlled-temperature ovens which permit operations to be carried out at ambient temperatures up to 200°C, the devices being run at their maximum rated dissipation for the ambient temperature used. The input leads for the 400 transistors in each oven are terminated in 40 separate modules housed in a double-bay distribution rack, a total of five of these racks being required for the 2000 transistors. Each module carries on the front panel a multi-way socket and an eleven-way switch which enables the devices to be selected ten at a time. An operator inserts a special plug with a pistol grip into the multi-way socket and selects the device required on the rotary switch. The multi-way plug has a flying lead connecting the device to the automatic measuring equipment and also incorporates interlock wiring, a monitor lamp, and a trigger switch for starting the automatic testing equipment. When the plug is inserted and the first device has been selected, the monitor lamp on the pistol grip lights up, provided that the data-handling equipment is in its start condition; operation of the trigger switch then starts the automatic testing sequence.



The parameter data of each device are recorded on a punched card and also in tabulated form on a typewriter. A separate punched card is used for each device, and it is necessary to record other identifying information on each card with the data, which consists of the date, time, and device number. The date is derived from a date-switch, the time from a digital clock, and the device number from a discrete coding system within the distribution racks. This block of information is punched out on the card (by an IBM punch) and typed in tabulated form (by an "Addo-x" printing tabulator) before any measurements are made. Whilst this punching and typing operation is being carried out, the device selected is still in its life-test dissipation condition. The illustration shows a general view of the equipment with the associated IBM card punch and "Addo-x" printer in the foreground. The distribution racks can be seen at the left of the picture.

On completion of this part of the record, the device is connected into the first of its parameter test configurations and a digital voltmeter is connected to the required test point. A delay of 100 milliseconds is introduced for the device to settle into its new circuitry and the digital voltmeter is given a "digitizing" pulse. When the digital voltmeter has completed its conversion, the digital measurement is read out into the card punch and the tabulator. During the period of time that the punch and typewriter are recording the information, the device is returned to full dissipation conditions. The transistor is then connected into the next test configuration, where it is allowed the same settling time, the digital voltmeter taking the next reading and its data read out to the IBM punch and the "Addo-x" tabulator. This process is repeated until all the required parameters have been recorded, when the card punch ejects the card and the tabulator makes a carriage-return and line-shift. The monitor lamp on the pistol-grip plug then indicates that the data-handling equipment can accept a new set of data, after which the operator selects the next device and the sequence of events is repeated.

Ten individual measurements can be made, and the design allows for any number of measurements to be programmed up to its present capacity of ten; however, should the need arise, additional measurements can easily be catered for by extra modules. The parameter-measurement and test-configuration units are separate, interchangeable plug-in modules containing their own constant-voltage, and/or constant-current generators (according to the type of measurement), together with the required number of circuit-switching dry-reed relays. The majority of measurements made (leakage, current gain, etc.) are direct-current, but some low-frequency a.c. measurements are also taken. Manual selection of individual parameter units is provided in the equipment, so that initial calibration and setting up of the test configurations can be carried out. An important feature of the equipment is the provision of a "local" socket, enabling devices to be tested automatically at room temperature without dissipation being applied. The equipment can therefore be used as a versatile high-speed transistor test facility.

Fully Automatic Small Broaching Machine

The first fully automatic model in their SPD.7/16 range of pull-down broachers has been designed and built by the Lapointe Machine Tool Company for IBM United Kingdom Ltd., of Greenock, Renfrewshire. This machine, designated the SPD.7/16A, will be used to broach internal splines on component parts for accounting machines at a production rate of 1000 parts per hour. Like its predecessors, the SPD.7/16 (manual) and the 7/16SA (semi-automatic), the new machine has a capacity of 7000 lb and a 16-in. stroke. Of particular interest is the fact that the machine can easily be loaded during the return stroke of the broach, thus substantially reducing loading time. Loading during the return stroke is achieved by means of a shuttle table suitably bored to take work-holding fixtures for locating the components.

A special feature is an additional work-holder pot container fitted to the side of the platen, to permit the assembly of six components at a time into a work-holder pot. This pot is then positioned in the work-holder during the return stroke. By using two pots, the components can be loaded and unloaded into the spare pot during the cut stroke. Another important feature of the design is that the broach lifter is easily adjusted to different lengths of stroke by moving it in accordance

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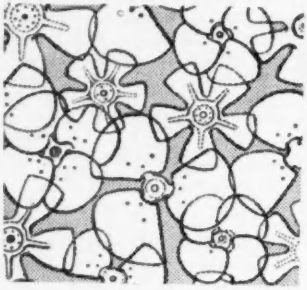

SMITHS TORRINGTON propeller fans, the widest range existing in this country, are promptly available from stock – 3" to 24" dia., either rotation, in a variety of pitches.

AIROTORS?
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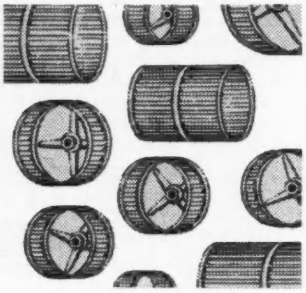

SMITHS TORRINGTON wide range of airotors are also promptly available from stock in following sizes – 1½" to 11" dia., widths from ¼" to 11", in steel or aluminium.

BOFFINS?
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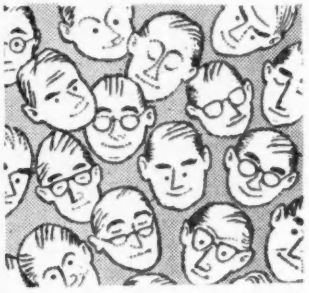

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Standardised sheet metal blower cases are now available to fit all sizes of SMITHS TORRINGTON airotors, both single and double inlet. This range offers the maximum versatility: piercings can be provided for a variety of motor mountings; special finishes can be provided as well as the standard Hammer Blue Green; individual performance curves supplied on request; speciality blowers can be designed and manufactured to your special performance requirements.

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Please write to us for illustrated literature and technical information. We shall be particularly interested in helping to develop new air-moving applications

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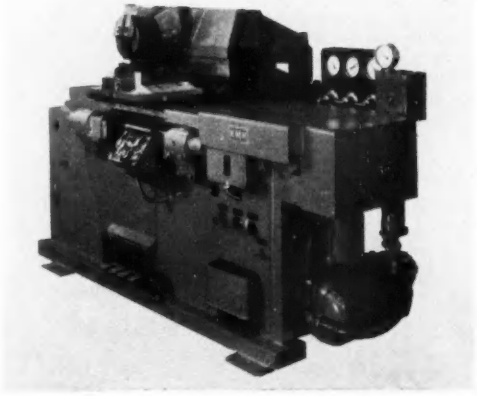
with a scale indicating broach length, all that is necessary being to loosen two bolts to make this adjustment.

No separate adjustment to the knock-off bracket is necessary, as it has been made an integral part of the broach lifter, so that the set-up can be quickly changed. Furthermore, the construction of the broach lifter is completely rigid, ensuring accurate alignment when the broach enters the component. The addition of the shuttle table and broach lifter does not limit the variable-speed and variable-stroke features which already exist on the basic SPD machine. Should a set-up be required using broaches for surface broaching an external shape, the broach lifter and shuttle table can be removed from the machine. The electrical circuit is interlocked to ensure that the shuttle table cannot be moved except when the broach is at the end of either the cut or return stroke.

Automatic Flash-Welding Equipment

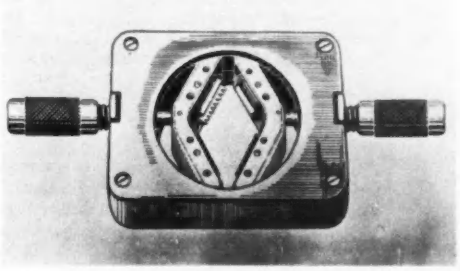
Produced by Electro Mechan-Heat Ltd., of Ettingshall, Wolverhampton, under licence from Electromécanique S.A., of Brussels, Belgium, the BAJ.32/120 automatic flash-welding machine utilizes "alligator" clamping in conjunction with a special air/hydraulic system to give high-speed closure of the jaws, pressure then being built up until a maximum clamping force of 24 tons is achieved. A special feature of the clamping arrangement is that both the table and the swivelling upper jaws are cast in high-tensile steel and are therefore sufficiently robust to withstand all clamping forces. The high clamping and forging pressures are obtained by means of an additional ram which intensifies the hydraulic pressure as soon as the primary ram has completed its stroke and closed the clamps. The moving table is operated by an air/hydraulic system, enabling the extent of its travel to be set accurately over a considerable range. Forging pressure can be applied at any point.

A specially contoured arm makes the machine particularly suitable for use on cylindrical components, such as wheel rims and small barrels. The maximum weldable cross-section is 2·33 sq in., and the maximum width of strip that can be accommodated between the arms is 11¾ in. With this width, cylindrical components down to 13¾ in. in diameter can be welded. With widths below 4¾ in., the diameter of the component can be as low as 9¾ in. The automatic welding sequence is started by a push-button from a small desk located at the front of the machine, a sequence control unit and an ignitron or magnetic contactor being housed in a separate cabinet. The entire welding operation, including movement of the table, can also be controlled manually. Each clamping jaw can be closed independently by means of foot-switches, and provision is made for simple adjustment of the jaws vertically for wear. All areas likely to be affected by weld flash are protected by thick copper screens, from which any steel particles can easily be removed.



Thread-Restoring Tool

An American tool for rolling all types of damaged and rusted threads back into shape, without actually removing any thread metal, has been introduced into the U.K. by G. E. Simm Engineering Ltd., of Sheffield. Designated the "Buckingham" thread restorer, the tool can be used to chase and restore all types of battered and rusted threads in a matter of minutes, including a full range of right-hand and left-hand, metric, Whitworth, S.A.E., and U.S.S. threads. Not only does it eliminate the need for elaborate sets of dies, but it also can be used in confined spaces and for restoring damaged threads to which a die nut cannot in some cases even be applied at all. Where the damaged thread is part of an assembly, the part usually need not be dismantled.



In operation, the tool is applied to the bottom thread with its blades in the direction of operation. The blade jaws are then closed until the die blades fit snugly into the pitch of the thread, after which the tool is turned manually towards the operator until it comes off the component. Five basic models are available, ranging from a unit with a handle swing of 3 in. for threads with outside diameters between ¼ and 1 in., to a unit with a handle swing of 9½ in. for threads with outside diameters between 6 and 12 in. In addition, each version can be supplied for two different thread cone angles, i.e., 60 and 55 deg., making a total of ten models. The illustration shows the Model 62040 tool, which has a handle swing of 5¼ in. and is suitable for threads with a cone angle of 60 deg. and outside diameters between 1 and 2 $\frac{3}{16}$ in.

Staked-in Printed-Circuit Connectors

Following an agreement between Magnetic Devices Ltd., of Newmarket, Suffolk, and the Elco Corporation, of Philadelphia, Pa., a new staked-in type of printed-circuit connector, designated the "Varicon", is now being marketed and will shortly be manufactured by Magnetic Devices Ltd. The major advantages of these connectors include their versatility, ease of use, and reliability of connection. The use of staked-in contacts permits high contact pressures without damage to the foil and also allows gold plating of both contact faces. Furthermore, with these contacts, not only can boards be connected to moulded printed-circuit connectors carrying the chassis

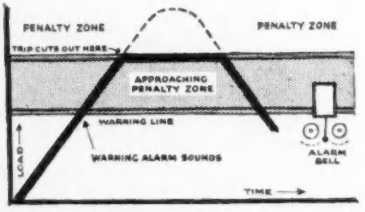
Load Factor Improvement

Most industrial electricity tariffs consist of a fixed charge based on the maximum demand for electricity by the works and a running charge for each unit (kWh) of electricity used. Broadly speaking, the fixed charge covers the capital cost of generating, transmitting and distributing equipment for the particular demand and the running charge covers the cost of generating the units.

Thus, if the factory maximum demand is reduced for the same level of consumption or is held constant for an increased consumption, the cost per unit will be reduced. This is termed improving the 'load factor': load factor being defined as the ratio of the number of units supplied during a given period to the number of units that would have been supplied had the maximum demand been maintained throughout the period; it is usually expressed as a percentage. Some ways in which load factor can be improved are:

SUPERVISION AND CONTROL OF MAXIMUM DEMAND

A maximum-demand alarm gives a warning when the maximum demand is about to be exceeded. One of the simplest devices has two warning contacts, but, as a useful addition, an auxiliary relay can be supplied so that non-essential load can be tripped automatically.



The Load Limiter, an automatic device, meets the requirements of medium and large consumers who wish not only to control their system loading to some target maximum but also to improve the load factor in order to increase the overall economy of the plant.

EXAMPLES OF REDUCTION IN MAXIMUM DEMAND

Broadly speaking, loads which contain some storage element can be transferred from on-peak to off-peak times. Examples are: charging electric batteries used in industrial trucks and road vehicles; pumping loads in drainage schemes; water pumping in quarries, gravel pits and other open-air workings; large cold-storage warehouses; ice-making factories in which cost of power is a sufficiently large item of the operating expense to make a reduced charge acceptable.

Many processes at times of peak demand can, under controlled conditions, tolerate a temporary reduction, or even cessation, of supply without any serious effect on the product. With electro-chemical processes such as in the manufacture of hydrogen peroxide no difficulty arises from periodic interruptions at short or even no notice.

In a plastics factory the management arranged for dies to be switched on by time switches one after another early Monday morning so at the beginning of work all dies had reached their operating temperatures. Previously they were switched on more or less simultaneously by hand when work started, resulting in an abnormally high demand.

In a certain chemical works compressed air is used for blowing out containers for plastic material. The nature of this operation is such that the consumption of air is spasmodic and irregular. The demand-recording meter in this works showed that the 18 kW motor driving the air compressor was frequently cutting in on top of the factory load, thus incurring a higher maximum-demand charge. In this case all that was necessary was to ensure that the air receiver only required charging at night-time or at other off-peak times. It was found that the existing receiver had such a small capacity that the pump had to operate to recharge it almost every time the blowing operation took place. This small receiver was therefore replaced by a receiver of large enough capacity to maintain the blowing requirements over the peak periods without further charging.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books are available on electricity and productivity (8/6 each, or 9/- post free)—'Higher Industrial Production with Electricity' is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

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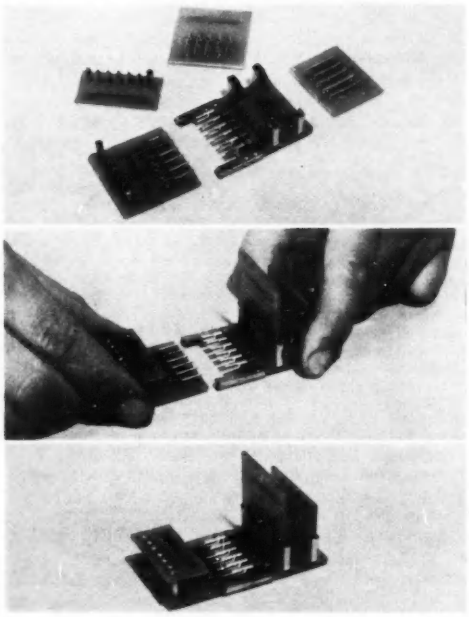
CUT HERE

wiring, but also printed-circuit boards can be connected to printed boards directly in any relative plane, as shown in the illustration, which gives examples of the ways in which printed-circuit boards can be joined together in different relative planes.

The basic feature of all "Varicon" connectors is the special fork-like hermaphroditic contact, each half of which has four coined surfaces mating at 90 deg. to each other. The contacts for mounting on to the printed-circuit board are supplied on disposable plastic strips, each contact being accurately positioned for immediate staking into the board. A simple type of staking tool for mounting on a small bench press can be supplied by the company, who, as an alternative, can stake contact assemblies to customers' own boards, if required. The contacts are made of phosphor-bronze, the standard finish being nickel plate and then gold plate. All contacts can be tested to 2000 V r.m.s. at sea level and to 600 V r.m.s. at 3·4 in. Hg. Because of the four accurately mating pairs of contact surfaces, contact resistance is extremely low, being of the order of 0·003 ohm. The contacts are rated at from 7 to 10 A, but have outstanding reliability for the passage of very low currents of only microsecond duration. The method of staking the contacts into the printed-circuit board and hence into the printed-circuit foil, not only ensures a low contact resistance, but also that the contacts are rigidly held in place. If desired, the contacts can be dip-soldered after staking, thereby making an additional connection. This is, however, not strictly necessary, but increases the force required to tear the contact away from the board from 50 lb to over 65 lb.

The moulded connectors are made of diallyl-phthalate and can be obtained with spacings between contacts of 0·1, 0·15, 0·2, and 0·3 in. A special feature of these connectors is that it is not necessary to sacrifice one of the contacts to provide polarization, as polarizing keys can be inserted into the groove taking the board without any obstruction to the contacts, even with a spacing of 0·1 in. As the connectors are precision-built, no dimensional problems arise. Even if the contacts are utilized in conjunction with a low-grade paper-based phenolic board, where moisture absorption is high, the expansion, contraction, or warping likely to be experienced is well below the maximum permissible limit for the correct insertion, withdrawal, and operation of the connectors.



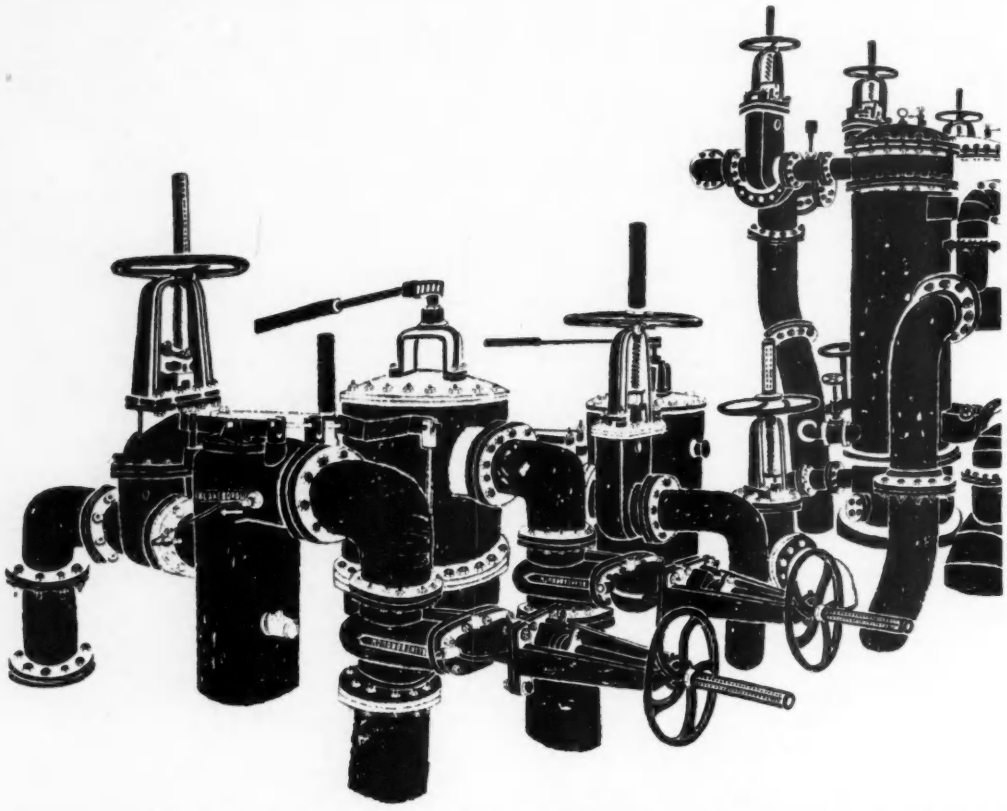
Electronic Air Purifiers

Produced in the U.K. by Thermotank Ltd., of Glasgow, by agreement with the Vita-Aire Process Co., Inc., the range of "Vita-Aire" electronic air purifiers, already well known in the U.S.A., is designed to produce a flow of negatively ionized air. The effect of negative ionization is the oxidation and complete destruction within a few seconds of all odours, smoke, dust, impure carbon particles, etc. in the air. In addition, it is stated that mould, mildew, and airborne bacteria can be eradicated completely in such places as breweries, cold stores, and food factories.

For domestic use and for hotels, restaurants, shops, laboratories, and offices, a range of twelve negative-ion generators is available for use in spaces with volumes between 4,000 and 15,000 cu ft. The generators, which operate on standard mains current and have a low power consumption, fit into a small plastics cabinet of attractive design, measuring $13\frac{3}{8} \times 6\frac{1}{4} \times 9\frac{3}{4}$ in. high. The cabinet, shown in the illustration, also houses the circulating fan and has an expanded-metal front and two simple controls, i.e., an on/off switch and a variable-output regulator. For industrial use, eight standard-size generators are available for volumes up to 200,000 cu ft. These generators can either be built into suitable casings and fitted with circulating fans, or they can be built into the ducting of existing air-conditioning or heating and ventilating systems. In the latter case, they are suitable for air flows of from 300 to 4,000 cfm. However, larger units can be constructed to order for cinemas, department stores, factories, ships, etc.

Automatic Programming System for Steel Rolling Mills

A new automatic programming system for steel rolling mills, developed by the Metal Industries Division of the English Electric Company Limited, uses punched cards to store the complete sequence of screwdown, manipulator, and mill-speed settings, as well as the number of passes in a rolling operation. The new system is an advance on the uniselector system introduced by the



THE MONEY THAT MANAGEMENTS SAVE THROUGH MOBIL ECONOMY SERVICE

More than £1,360 saved in a year at J. Blakeborough & Sons Limited

TAKING POSITIVE ACTION to cut maintenance and lubrication costs, J. Blakeborough & Sons Ltd., world famous valve manufacturers, consulted the experts—Mobil. After accepting their recommendations, and applying the correct lubrication programme, Blakeborough found that they had made direct savings of over £1,360. Indirect savings were estimated at a further £2,100.

World-wide experience of industrial lubrication

This example of the value of Mobil Economy Service is typical of many that could be cited from almost every industrial area of the world. In all these areas, the world-wide Mobil organization is applying more than 90 years' experience to the cutting of lubrication and maintenance costs.

One plan to meet all lubrication needs

The value of Mobil Economy Service is the value of expert knowledge methodically applied: it is a matter of assessing all the lubrication needs of a business collectively; considering how they can best be met with the fewest different lubricants in the smallest quantities; and making sure that everyone concerned knows how to use the lubricants to the best effect with the absolute minimum of work. The astonishingly large savings that are often achieved are the measure of the experience and skill that Mobil bring to the consideration of every lubrication problem.

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company two years ago, offering a greater programme-storage capacity than can be economically obtained with uniselectors. The benefits, however, are the same and enable operators to work more easily and to produce more steel of more consistent quality in a given time. The first installation of the new system is at the Hallside reversing billet mill of Colvilles Ltd., where it is being used for controlling the screwdown.

The system consists of three basic units, i.e., a card store, a card punch, and a card reader. The cards, of tough plastic, $\frac{1}{32}$ in. in thickness, are available in nine different colours, each with an identification tab, the special storage case holding 100 cards. The card punch is hydraulically operated and is so arranged that the keys remain depressed, enabling them to be checked before a complete line is punched. All the information necessary for one pass of the mill can be stored on a double line on the card, which is advanced section by section for each pass. This method of operation avoids the need for an intermediate memory store, since the pass information remains under the card reader for as long as required. A card can be advanced through the reader either by single passes or as a complete rolling operation. After completing the programme, the card resets automatically, and can be used again or rejected, as required.

The sensing devices used are photo-transistors, the output from which is amplified by a transistor amplifier controlling small plug-in relays for operating the various position-control systems. All components, with the exception of the relays, are mounted in a standard plug-in "Datapac" unit of the printed-circuit type. Faulty units can be located by a test card, and there is a parity check on all operations. The system is automatic, but the operator can always take over manual control to correct rolling faults.

High-Precision Industrial Liquid Meters

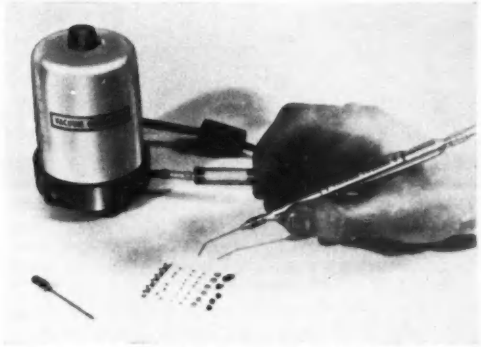
Based on the measuring unit incorporated in their well-known "Meteor" dispensing pumps for petrol, the new Model 2PM/3 "Micro-Meter" announced by the Wayne Tank & Co. Ltd., of Bracknell, is capable of dispensing liquids with an accuracy of $\pm 0{\cdot}125\%$ over an operating range from 120 to 1200 gph and, as such, has a far higher standard of accuracy than has hitherto been associated with industrial meters. To permit micro-adjustment after installation and to obtain the full accuracy of which the meter is capable, a special calibration device is fitted. This device is operated by a readily accessible external knob, one graduation of the knob representing a variation of 1 dram per gallon (about 0·04%). A total variation of $4\frac{1}{2}\%$ can be effected in this way.

The meters, which are constructed of stainless steel and high-duty non-corrosive aluminium alloy, incorporate a large numeral-type counter to record the amount dispensed, with zero reset. In addition, a totalizing counter is included for recording the total throughput. If required, the meter can be supplied with a ticket-printing attachment for providing a permanent record of individual transactions. A special arrangement of inlet and outlet ports enables the meter to be removed for service without disturbing pipework. A specially designed aluminium strainer with a 120-mesh Monel-metal screen, readily removable for cleaning, can be supplied for installation on the inlet side to protect the meter.

Although they are not available at present, it is hoped to introduce similar meters fitted with automatic stop mechanism and valves to enable quantities to be preset and deliveries to be terminated automatically at the end of delivery.

"Vacuum Tweezers" for Handling Miniature Components

As announced by the sole concessionnaires in the U.K., L. E. Simmonds Ltd., of Harrow, Middlesex, the V-100 "vacuum-tweezer" system made by The Vacuum Tweezer Co., of New Jersey, facilitates the handling of miniature components and enables even the most delicate parts to be picked up with far less risk of damage than is possible with mechanical handling arrangements.



The system, which is portable and self-contained, operates from a standard a.c. mains supply and consists of a special miniature electromagnetic vacuum generator and a vacuum pencil fitted with a removable stainless-steel pick-up tip, various shapes and sizes of which are provided. The vacuum pencil is similar in size to a propelling pencil and is connected by flexible tubing and a dirt filter to the generator, which is provided with a control for adjusting the degree of vacuum. To lift and hold a component, the operator merely touches its surface with the pick-up tip and at the same time covers a small opening in the body of the pencil to maintain the vacuum. Uncovering the opening releases the vacuum and the component.

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but we are not taking over the function of the Royal Arsenal. Confidentially, all the components of this extraordinary weapon are nylon mouldings produced by us for various industrial uses.

Every week our design engineers assist some new client by producing a nylon moulding which, to-day, can replace a more conventional material and yet do its job more efficiently but usually costing less to produce.

A technical breakdown of this exclusive weapon is freely available to any discerning engineer with an eye to the future and—beautiful spies, please note that we are working in NYLON FOR ENGINEERS not nylons for the weaker sex.

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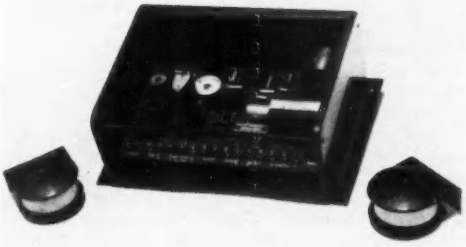
New Materials, Processes, and Equipment

Ultrasonic Burglar and Fire Detection Equipment

Fully transistorized and incorporating automatic sensitivity control, the new "Sonalarm" burglar and fire detection equipment developed by Electronic Laboratories (Hendon) Ltd., of London, N.W.2, is stated to be the first of its kind in the world and is so selective that it will ignore the presence of "harmless" intruders, such as cats and mice, but will respond instantly to the presence of intruders from outside or of those who have concealed themselves in cupboards, etc., during working hours and later emerge. In addition, it obviates the disadvantages of "perimeter" defences involving the use of tubing or wiring at window or door areas, these defences usually sounding an alarm only when a previously concealed intruder is on his way out. Another advantage is that, although the equipment depends on electrical supplies, it will still continue to function for several hours after the power supply has been accidentally or deliberately cut off and, indeed, will even give a warning if the supply is not reconnected after this period.



The principle of the instrument, which is contained in a small case, is that it emits ultrasonic waves to cover not merely an area, but the whole volume of a room, these waves building up a standing-wave pattern and being received back into the instrument. Should an intruder enter the room by any means, the standing-wave pattern is immediately disturbed, causing the contacts of a relay to close and to ring a bell, switch on the lighting system of the building, or send a warning to a central control post or directly to the police. On the other hand, the standing-wave pattern can just as easily be disturbed by a flame, so that an incipient fire will sound the alarm equally effectively. The automatic sensitivity control, which operates in a manner similar to that of the automatic volume control of a radio set, enables the instrument to continue to differentiate between cats, mice, etc. and human intruders, thus eliminating the possibility of false alarms. Also, it enables the level of sensitivity required in, for example, an empty warehouse to be distinguished from that required when the warehouse is filled with goods. The entire equipment is of robust and reliable design, so much so that it will operate satisfactorily for indefinite periods of time, and the chance of a component failing in use is so remote as to be considered of no practical importance.

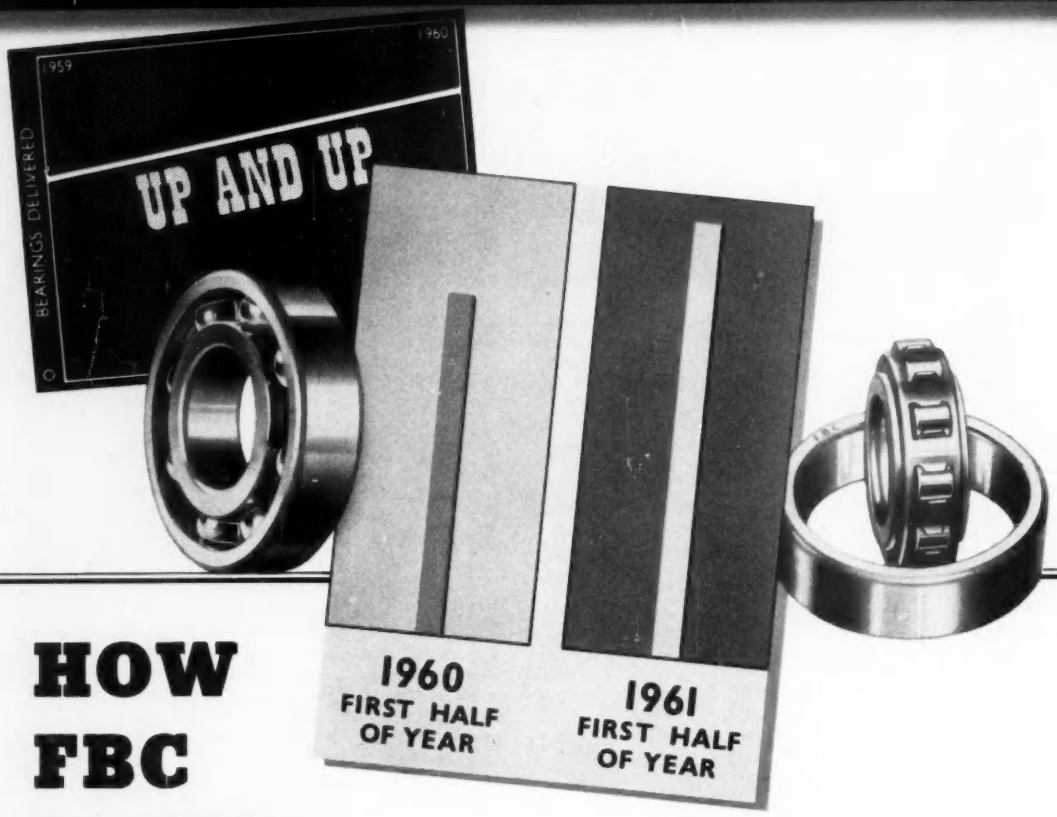
A special version, known as the "Vaultalarm", is available for the protection of bank vaults, which are sometimes vulnerable to intruders who may breach the vault from outside or who may actually attack the backs of safe-deposit boxes lining the walls, without entering the vault itself. For this reason, in addition to ultrasonic protection by the "Sonalarm", the equipment incorporates a specially designed microphone system which disregards "harmless" noises, but immediately responds to noises produced by the use of metallic drills and other tools.

Automatic Drill for Printed-Circuit Boards

A new automatic drill, the first of its kind in the world specifically designed for the rapid and economical drilling of component fixing holes in printed-circuit boards, has been introduced by Ferranti Ltd. The machine, which is now in limited quantity production at the company's Edinburgh factory, is already being used successfully for drilling the printed-circuit boards required for the Ferranti "Atlas" high-speed computer and the "Argus" process-control computer.

The machine basically consists of two drilling heads for either tandem- or single-spindle operation, a hydraulically operated co-ordinate table carrying the printed-circuit boards, and a control system for the drilling action and table movement, enabling the machine to work unattended, except for loading and unloading. The Dumore Series-20 drill heads incorporate a series-type motor with a chuck at one end of the shaft and a three-blade vane-type compressor at the other end for providing compressed air for feed thrust. The rotational speed of the spindle is automatically governed by the drill size and the workpiece material. The larger drills offer more rotational resistance, thereby slowing down the motor and automatically providing the correct speed for a given drill. Speed is governed primarily by the setting of an air pressure regulator, the proper regulator setting for a given drill size automatically providing the correct speed (2500 to 7500 rpm) and feed rate. The chuck capacity is up to $\frac{1}{32}$ in., and the maximum drilling thickness in synthetic-resin-bonded paper is $\frac{1}{4}$ in. An important feature of the machine is that the operating and control mechanisms are completely shrouded against the ingress of swarf. Maintenance is confined to the topping up of the hydraulic oil reservoir about once every six months.

The drilling table, which has an area of 20 × 14 in., is moved parallel with or at right-angles to the front of the machine by means of hydraulic jacks. Positioning of hole centres under the drills is carried out in two stages, in the first of which rough positioning is achieved by a perforated template and a photo-electric cell, while, in the second stage, accurate positioning is produced by a mechanical indexing system, using the meshing of a half-nut and a precision rack. A positional accuracy of



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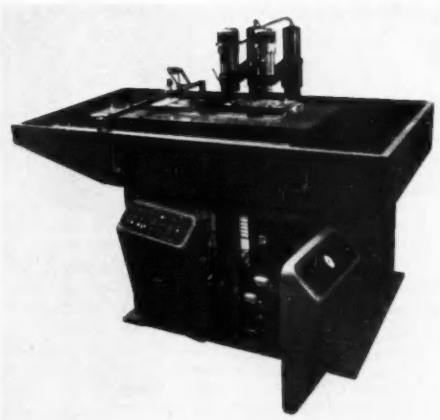


±0·001 in. can be obtained, with repeatability within 0·001 in. Drilling is carried out to a grid system, the holes being drilled in a systematic pattern of rows and columns. The basic spacing between rows of the grid system is determined by the pitch of the thread of the precision rack associated with row alignment. A typical pitch is 20 threads per inch, giving a spacing between rows of 0·050 in. or multiples thereof. A similar precision rack is used for column alignment. The basic spacing need not be the same for rows and columns.

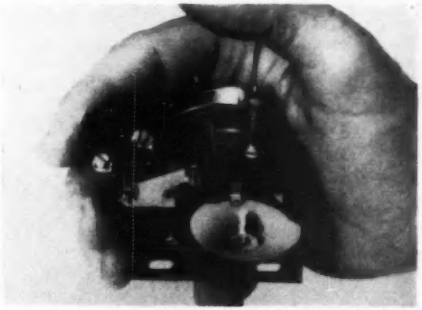
The perforated template is mounted on an extension of the drilling table and, whenever a hole in the drilling area of the template coincides with a light beam, the photo-electric cell is stimulated and provides a signal to the control system. This signal initiates cut-off of the oil flow to the hydraulic jacks stopping the drilling table, followed by application of oil to the half-nut mechanism to mesh the half-nut with the precision rack, thereby accurately locating the table and locking it in position. The drilling action is then initiated by switching electrical power to the drills. On completion of the drilling action, a signal from the drilling head is fed to the control system to release the half-nut from the rack and to re-start the flow of oil to the jacks which move the table. This process is then repeated for the next hole in the template.

When a row of holes is completed, the drilling table moves to bring the adjacent row into line with the drilling heads. Movement of the drilling table to bring the next row into line is controlled by two columns of row-marker holes in the template, each row of the drilling pattern having an associated row-marker hole. These holes stimulate the photo-electric cell, and the resulting signal to the control system causes the table to move up to the next row and along that row. When the last hole is drilled, the drilling table returns to its start position and then stops.

The machine can accommodate a single stack (up to $\frac{3}{8}$ in. deep) of one or more printed-circuit boards with dimensions of up to $12\frac{1}{2}$ in. × 18 in., with maximum drilling dimensions of $11\frac{1}{2}$ in. × $17\frac{1}{2}$ in. Alternatively, it can accommodate two stacks of identical boards for simultaneous drilling (each stack up to $\frac{3}{8}$ in. deep and one or more boards per stack), each with dimensions up to $12\frac{1}{2}$ in. × $8\frac{1}{4}$ in., with maximum drilling dimensions per board of $11\frac{1}{2}$ in. × $7\frac{1}{4}$ in. The rate of output of completed boards is dependent on the pattern of holes to be drilled and the number and thickness of boards forming the stack. For example, in the case of boards for the "Argus" computer, each of which measures approximately $5\frac{1}{2} \times 7\frac{1}{2} \times \frac{1}{16}$ in. and requires 288 holes, two stacks of four boards each are completely holed in $14\frac{1}{2}$ min, representing an average time of about 108 sec per board, including loading and unloading.

Miniature Synchronous Single-Cam Timers

Weighing just over 11 oz and with overall dimensions of $2\frac{3}{4} \times 2\frac{1}{4} \times 2\frac{7}{8}$ in. high, the new "ElRemCo" Type OE1 miniature single-cam timer is a simple and inexpensive unit which, by virtue of its small size and reliability, has a wide range of applications, ranging from the automatic operation of domestic oil-firing equipment to the control of vending machines. Other advantages include ease of mounting and an extremely wide variety of time cycles, ranging from a few seconds to 24 hr.



The timer, which is driven by a synchronous motor, is fitted with a single change-over switch and can be supplied for operating voltages of 110 and 220/250 V, 50 or 60 cps. The switch ratings are 5 A at 250 V a.c., or 5 A at 24 V d.c. The timer can be used to close one electrical circuit for a specified interval during a fixed continuously repeating overall time cycle or, when initiated by an external switch or push-button, a fixed single-cycle and stop switching action can be obtained.

Magnetic Level Indicator for Corrosive and Other Liquids

Combining simplicity of design and low cost with absolute reliability, a new magnetic level indicator announced by Alan Cobham Engineering Limited, of Blandford, Dorset, has a wide range of industrial applications, but is especially suitable for use where corrosive, toxic, volatile, inflammable, radioactive, valuable, or pressurized liquids are involved, and where liquids must be kept free from contamination or oxidation by exposure to the atmosphere. A special feature of the indicator is that it can be fitted from above or below a tank. Thus, on road-tankers, it is normally fitted on top for ease of access, whereas it can be installed underneath large storage tanks, thereby avoiding the expense of building ladders and catwalks, as well as the possible danger of having to use them. Similarly, because of its sealed design, spillage and fire risks from tanks containing inflammable liquids are greatly reduced, while tanks containing dutiable liquids, such as wines and spirits, do not require the presence of a customs officer for sealing and resealing each vessel when levels have to be checked.

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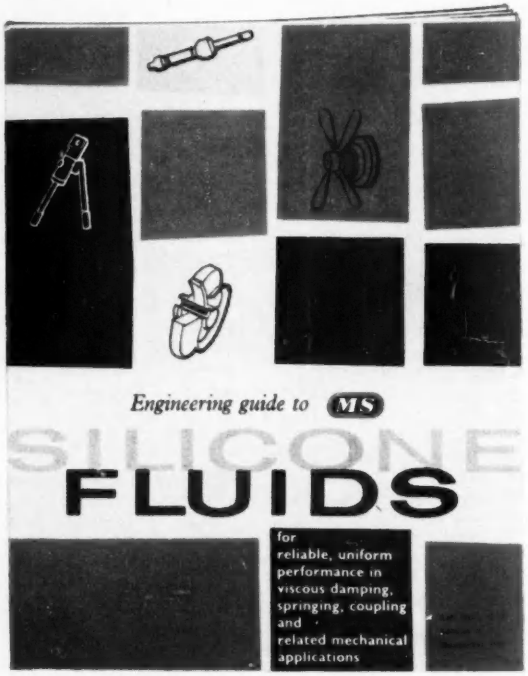
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Essentially, the indicator consists of a cellular-plastic or metal float built around an annular steel magnet, which is free to slide up and down a sealed tube fitted into the upper or lower face of the tank from outside and carrying a graduated dip-rod with a second magnet. When the dip-rod is lifted (or lowered) to check the level of liquid in the tank, it is held by attraction as soon as its own magnet comes level with the float magnet. After the reading has been taken, the dip-rod is pushed pack into the tube and locked. At present, three basic types of indicator are being produced, all of which have aluminium-alloy tubes with flanges tested to 250 psi, but differ with respect to the floats used. Thus, two types have foamed polyvinyl chloride floats capable of withstanding pressures of 125 and 250 psi respectively and are therefore suitable for such liquids as butane and propane, as well as ordinary hydrocarbon fuels, while the third type has a low-pressure light-alloy float for use with such solvents as acetone or in applications where the temperature exceeds 50 C, e.g., in trichloroethylene baths. A fourth type, made of stainless steel throughout, is being developed primarily for the pharmaceutical and food industries or for use in hospitals. Indicators in other materials can, however, be made to order.

Since the indicator is float-operated, different readings will be obtained in liquids of different specific gravities. However, by using a biscuit-shaped float with a large surface area and small depth of flotation, the possible error is small and can be corrected by means of a simple adjustment. Furthermore, the buoyancy of the floats can be adjusted during manufacture so that they can be used, if required, to check the levels of only the heavier liquid in a vessel containing two liquids of different specific gravities. The indicator itself is available in sizes up to 12 ft in length, with the dip-rod graduated in feet, inches, and tenths of an inch or in centimetres. Alternatively, the rod can be furnished plain with a special marking kit for calibration by the operator himself.

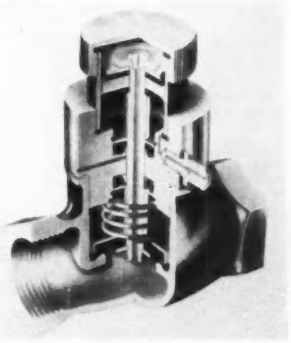
Micro-Miniature Soldering Tweezers

A new type of soldering instrument, specially intended to meet the need for precision soldering in laboratories and in production lines for micro-miniature modules, diodes, relays, and transistors and other semiconductors, as well as in such applications as the soldering of jewellery, etc., is being manufactured by Oryx Electrical Laboratories Ltd., of Worthing, Sussex, and is being marketed exclusively by W. Greenwood Electronic Ltd., of London, N.W.2.

Essentially, the instrument, which is fully patented, comprises a handle carrying two limbs which form the arms of a pair of tweezers fitted with tips of $\frac{1}{32}$ in. diameter, each tip being heated by a separate 6-V heating element in each limb. The tips are made of solid nickel to ensure long life, and their replacement, when necessary, is a simple operation, merely involving unscrewing a bush in the handle and fitting a new limb, complete with heating element. A maximum tip temperature of 290°C can be obtained, and the instrument is extremely light and easy to manipulate by means of a very slight finger pressure. An unobstructed view of the work is obtained at all times for close precision soldering, and the operator can hold the work and provide simultaneous heating on both sides with only one hand. In this way, heating times are considerably reduced and cold joints are virtually eliminated.

Remote-Control Globe Valves for Liquids or Gases

Available in sizes from $\frac{1}{2}$ to 3 in., the "Hydrovalve", announced by The Perrett Control Co. Ltd., of Hounslow, Middlesex, is a globe-type valve designed to control the flow of liquids or gases up to a pressure of 125 psi and operated pneumatically or hydraulically by remote control. The valve is simple in design and positive in action, and its size is only two-thirds that of an equivalent manually operated valve. All components are readily accessible for servicing, and the valve action is non-concussive, thereby eliminating problems of hammering in fluid systems. Also, because it is constructed throughout in non-ferrous metals, with synthetic-rubber valve seats, piston cups, and gland seals, it can be used with a wide variety of liquids or gases.



The valve, which is particularly suitable for inclusion in process-control and automation systems, is of the "under-and-over" type, with a renewable disc seat, and has the special feature that the line pressure itself ensures a tight shut-off. When the valve is closed, the liquid or gas entering the inlet passes through the hollow spindle, fills the cylinder at the top of the unit, and acts on a piston. This piston has a greater surface than the valve disc and keeps the seat firmly in the closed position, despite variations in line pressure. Application of the control pressure to the lower part of the piston overcomes the downward thrust and causes the valve to open. The rate of opening is controlled by the size of an interchangeable nozzle fitted in the bore of the hollow spindle, and the control pressure (40 to 100 psi) necessary to open the valve is considerably lower than the line pressure. When the control pressure is released, the line pressure on the top of the piston, aided by a small phosphor-bronze return spring, closes the valve. The rate of closing is again determined by the size of the nozzle controlling charging of the upper cylinder, and it is this feature which produces the non-concussive closing effect.

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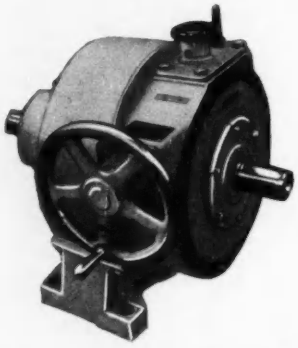

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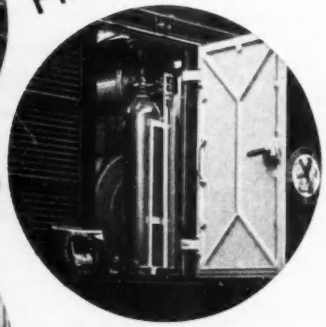
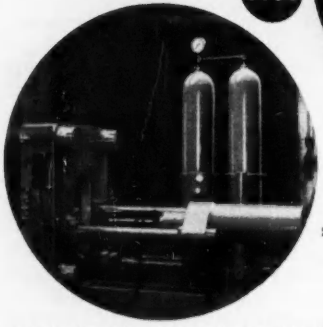


then the cylinder



1. 50 lbs. Seamless Steel CO_2 Cylinders, part of the "Pyrene" fire protection equipment fitted to British Railways 1,000 h.p. diesel electric locomotives. (With acknowledgements to 'English Electric', The Pyrene Company Ltd. and British Railways).

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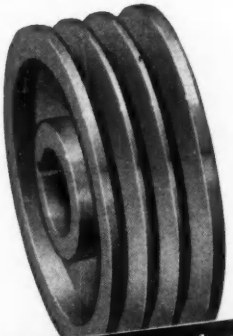

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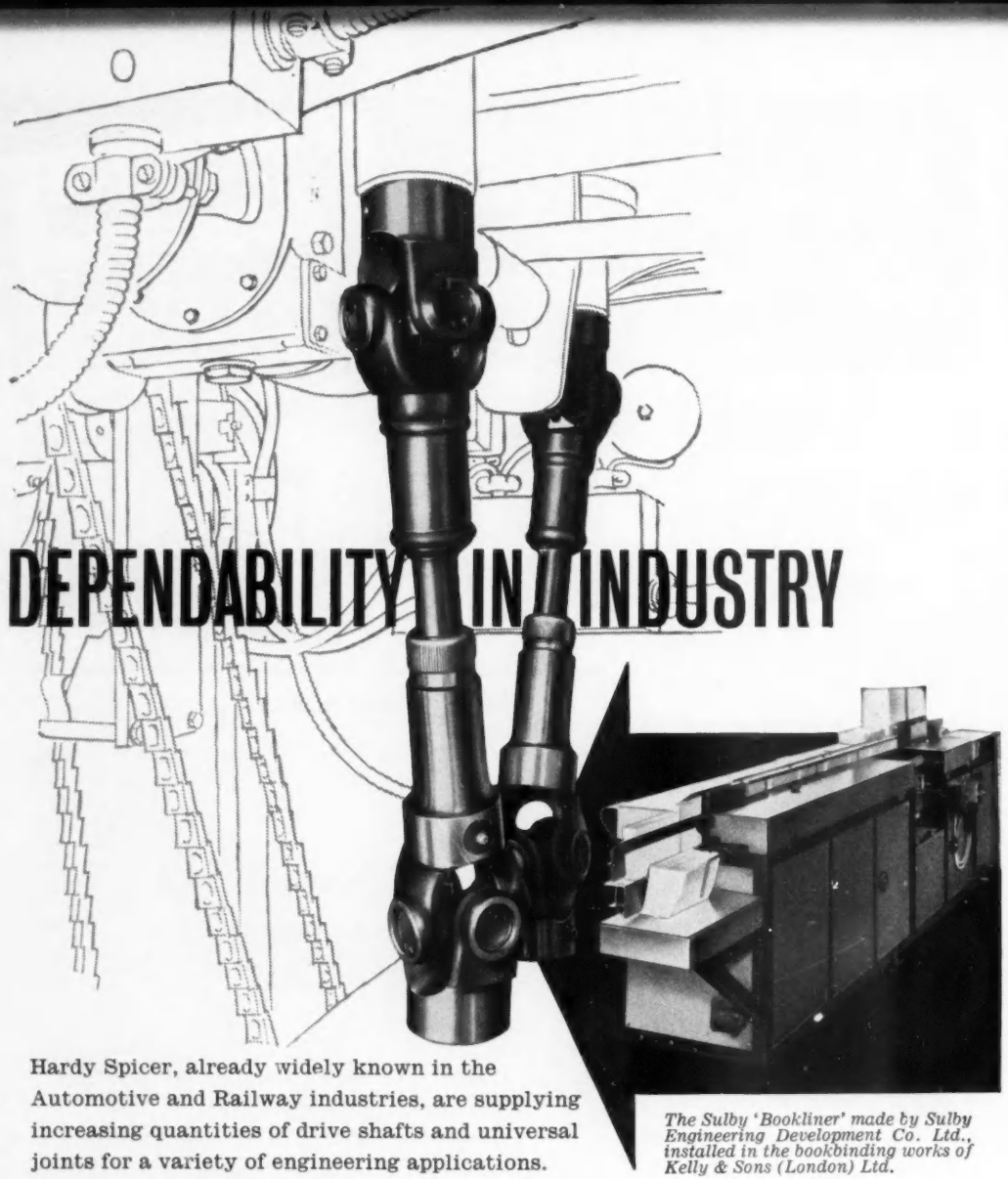

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Hardy Spicer, already widely known in the Automotive and Railway industries, are supplying increasing quantities of drive shafts and universal joints for a variety of engineering applications. Typical of these are the two universal-jointed shafts illustrated here, used in this case to drive the feed conveyor in a "Bookliner" book-binding machine.

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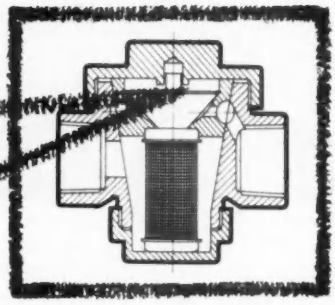

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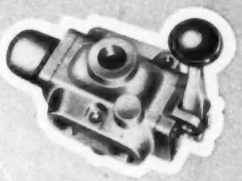
Threaded body or subplate mounted design for pressures up to 2500 psi or 5000 psi, 7 different spool configurations.



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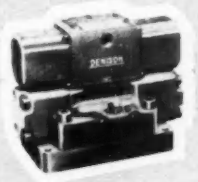

DENISON AXIAL PISTON EQUIPMENT

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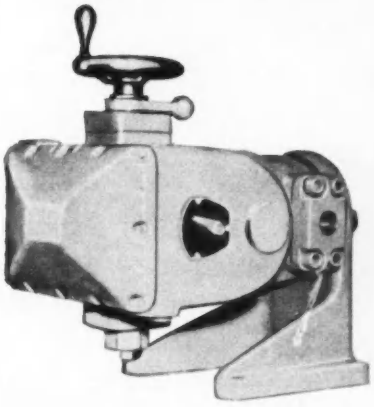

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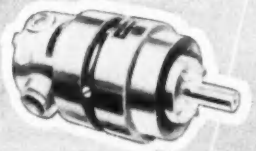

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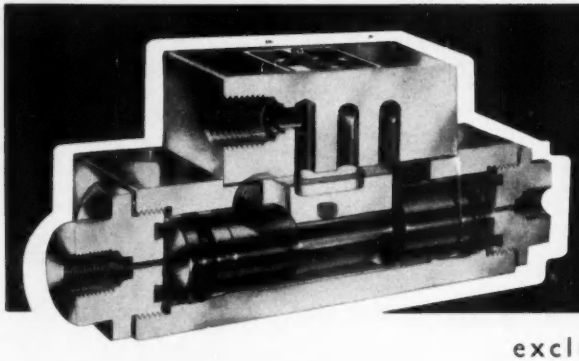

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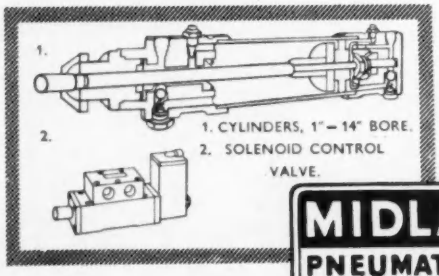

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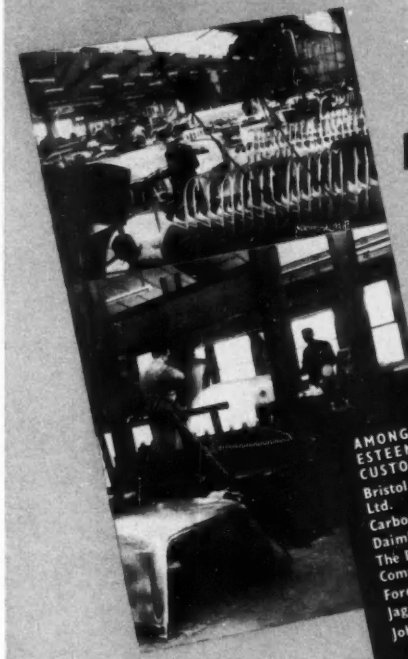

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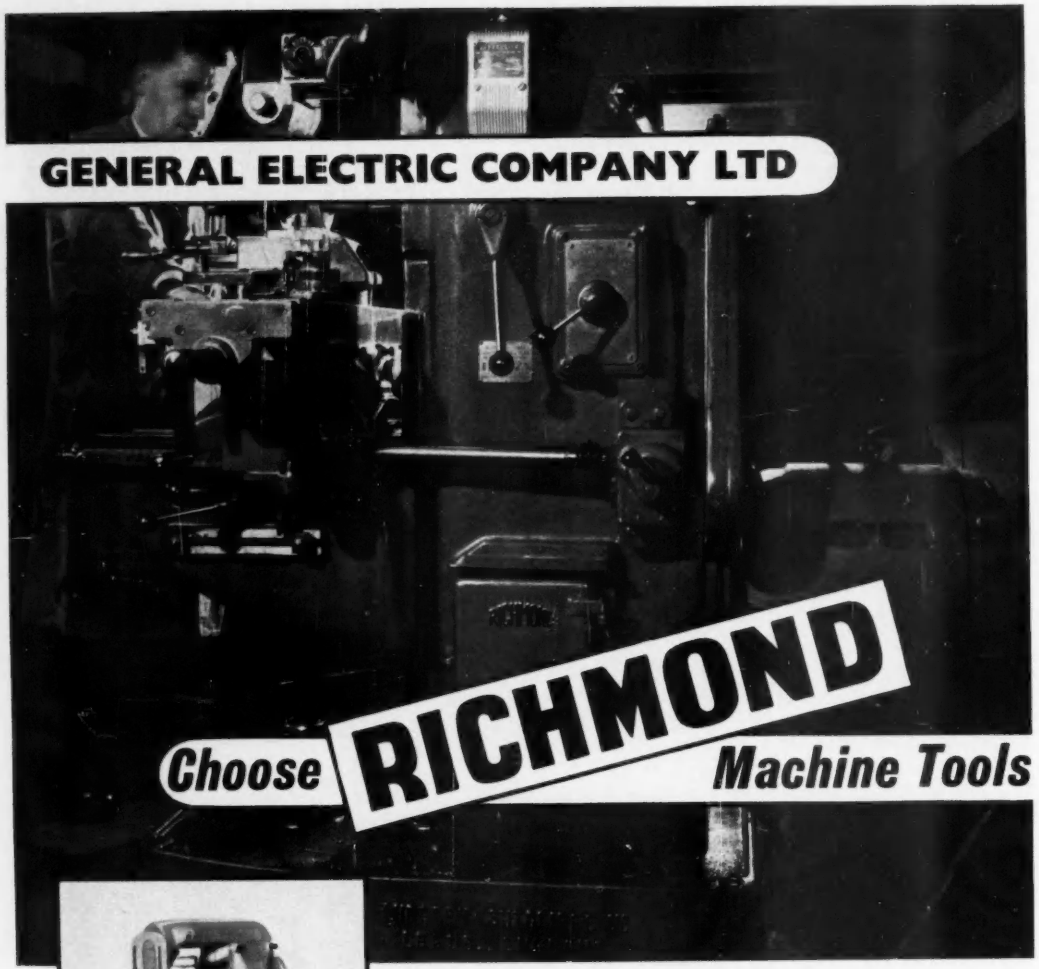

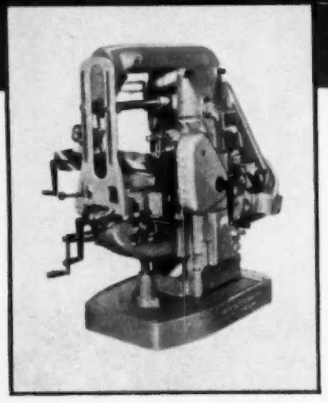

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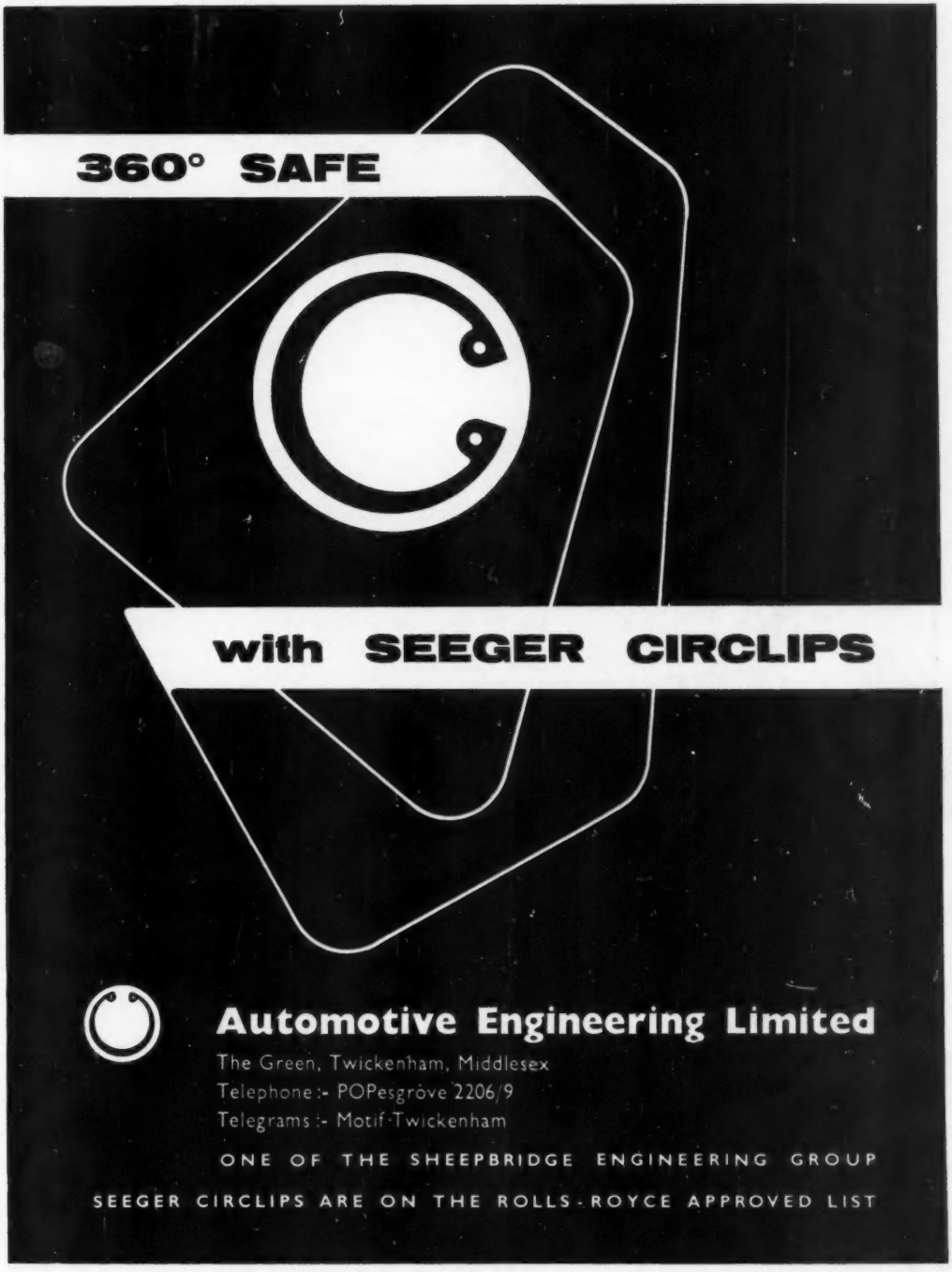
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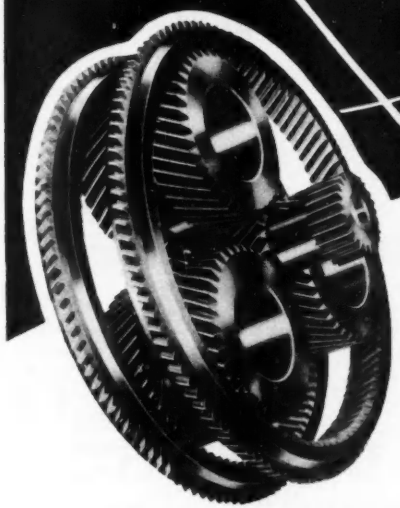

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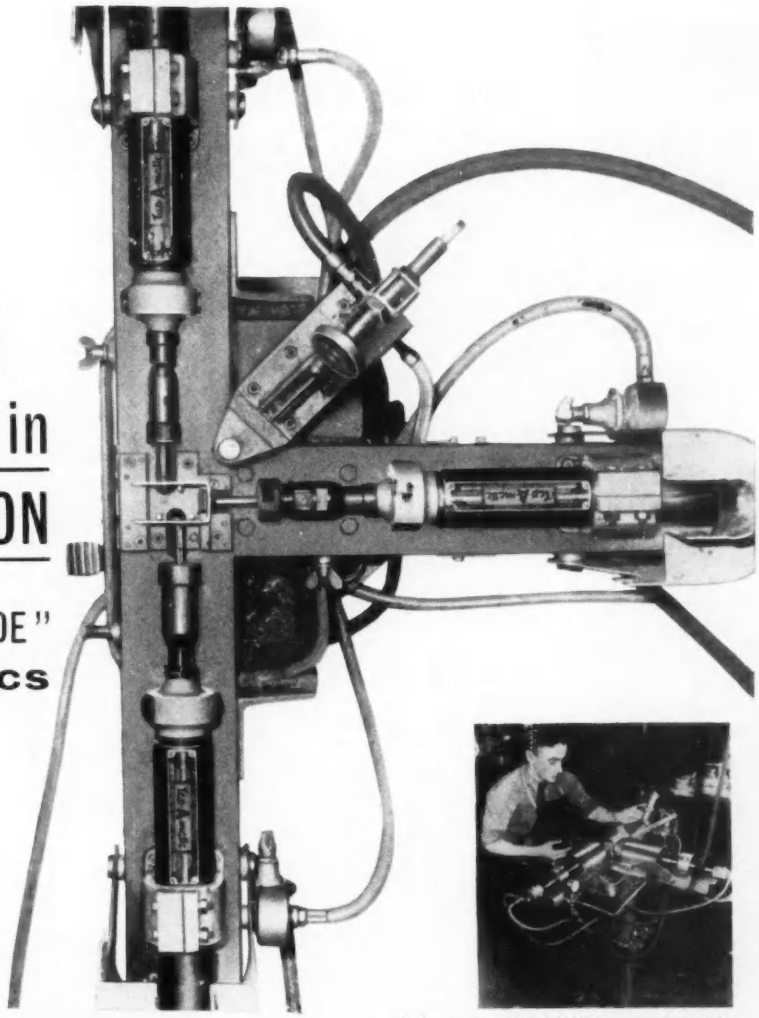

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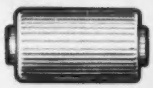

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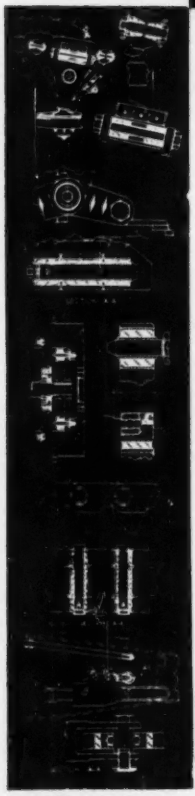

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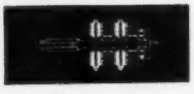

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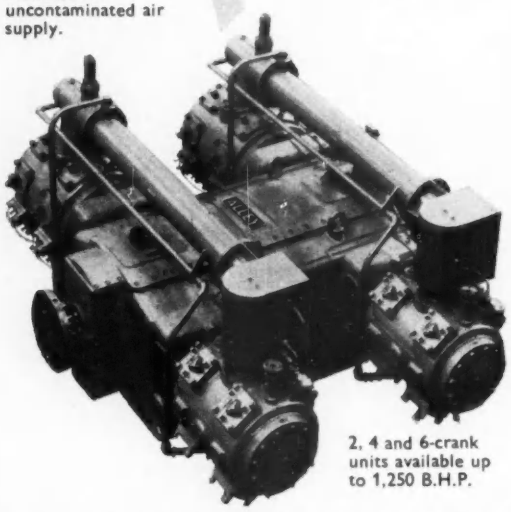

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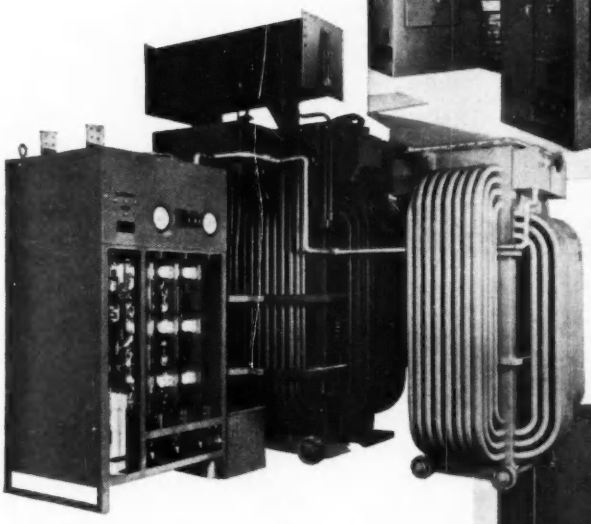

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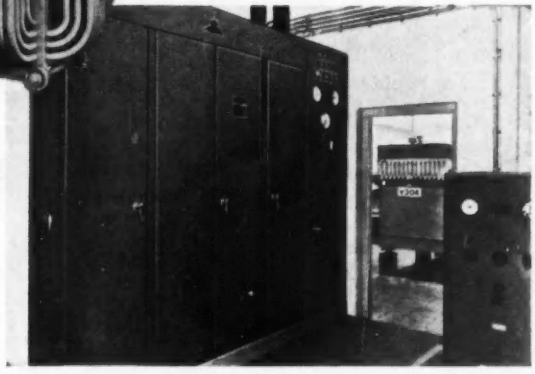

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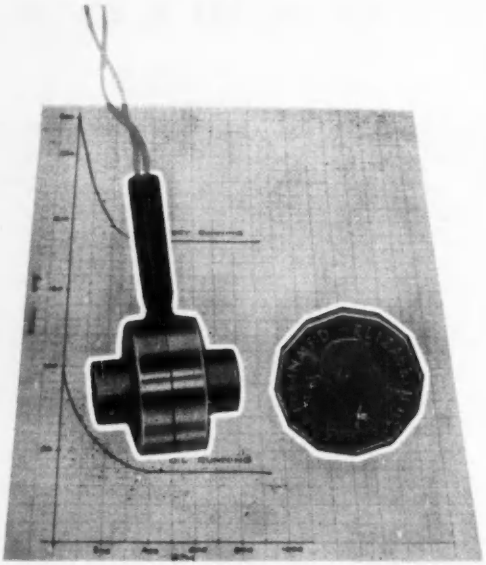
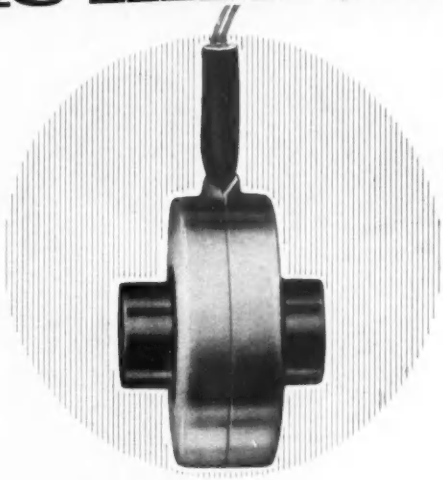


down to the minute



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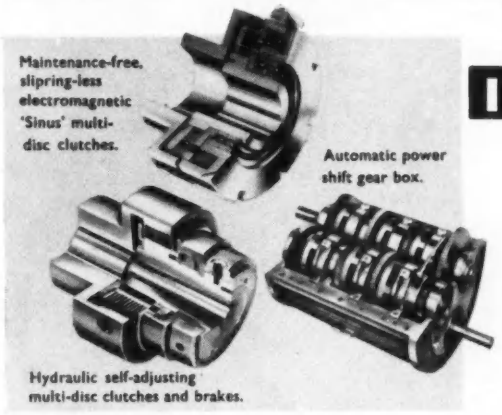
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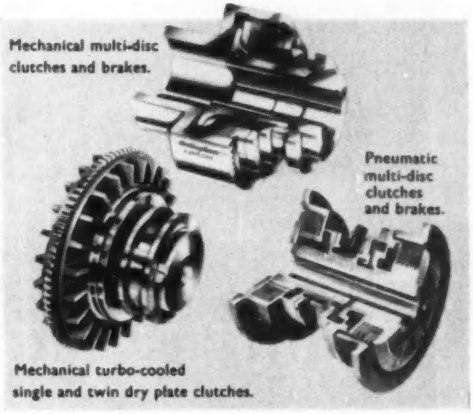
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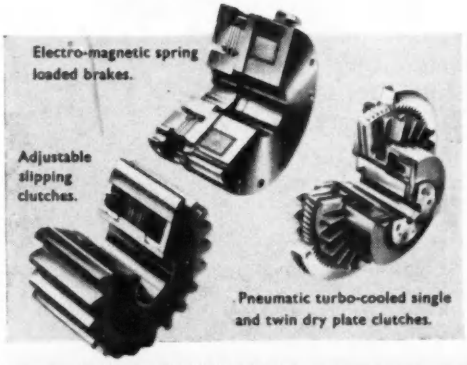
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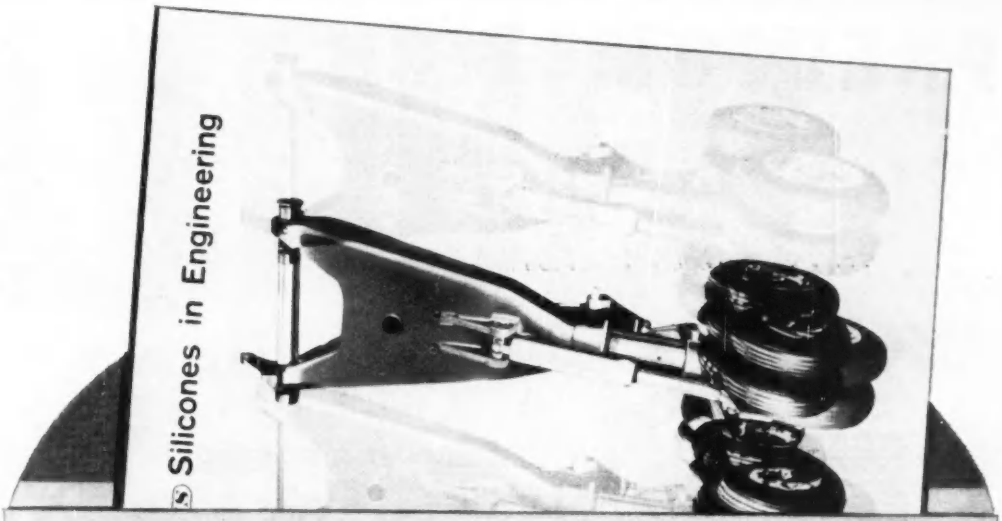

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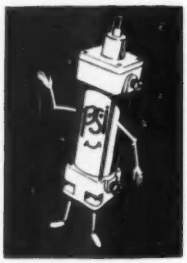

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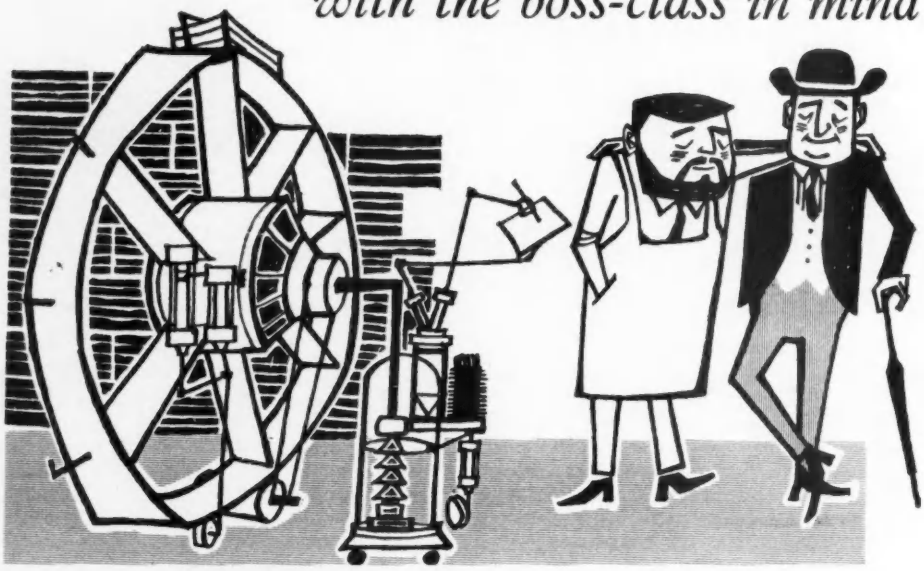

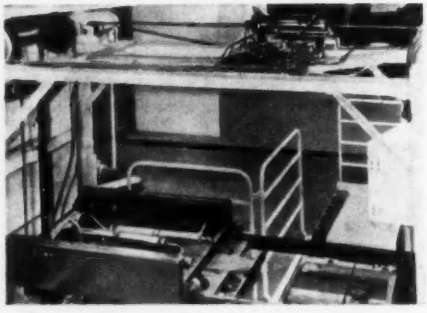

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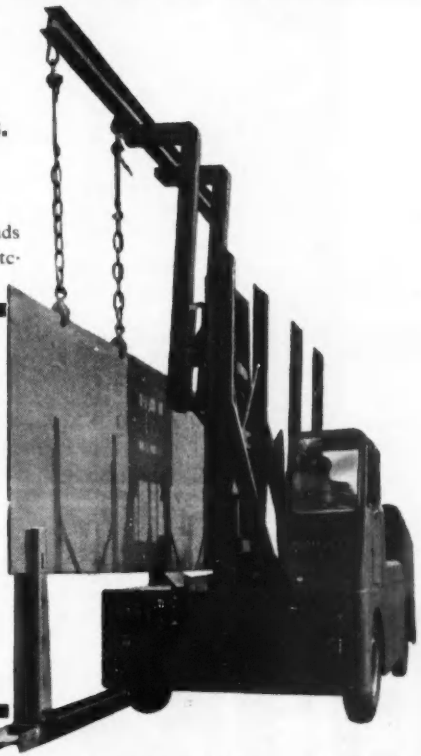

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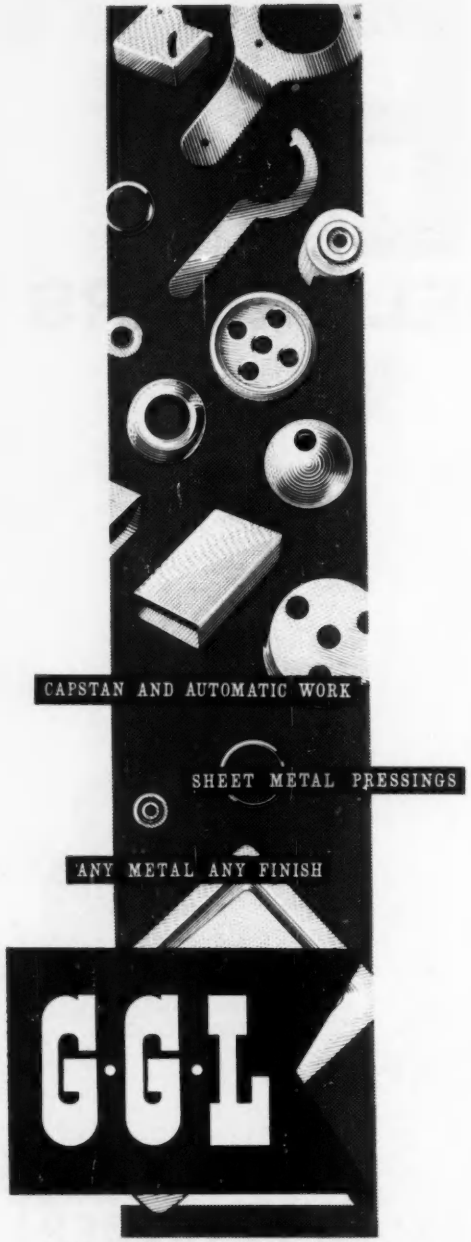

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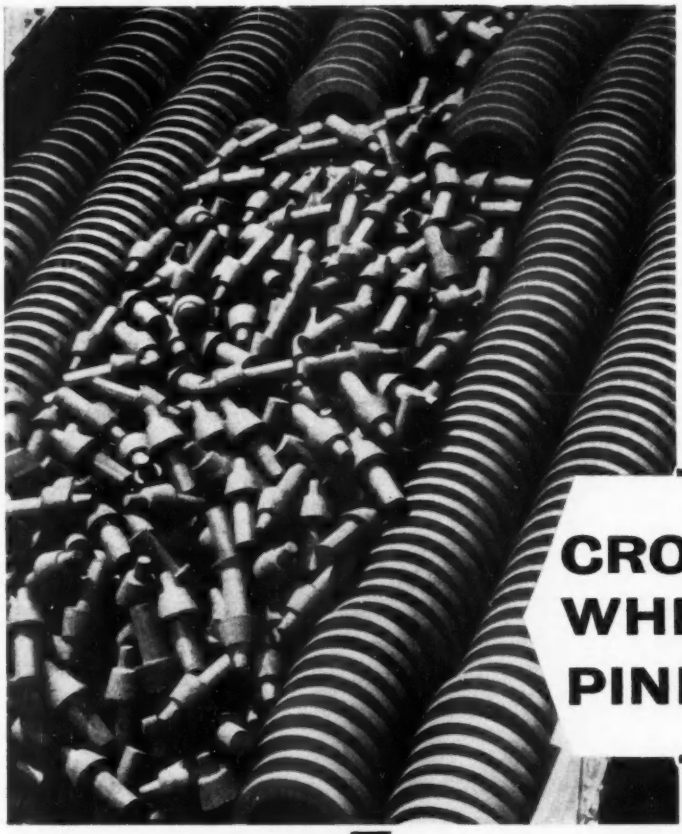

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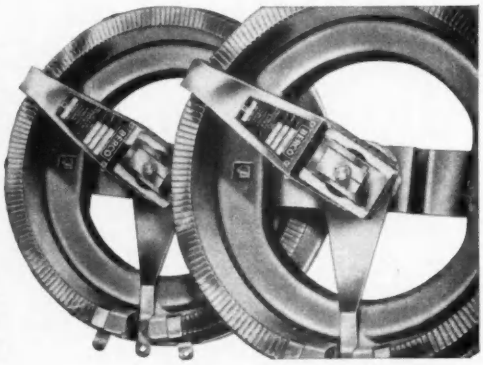
3	15.8	18.3	100	2.74	3.16
5	12.25	14.2	150	2.24	2.58
7.5	10.0	11.5	200	1.94	2.23
10	8.66	10.0	350	1.46	1.69
15	7.06	8.18	500	1.23	1.43
25	5.48	6.32	1000	.866	1.0
50	3.87	4.47	2500	.548	0.634



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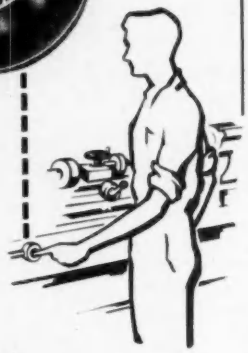

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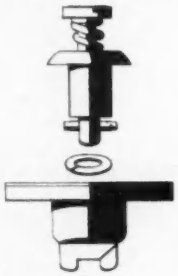

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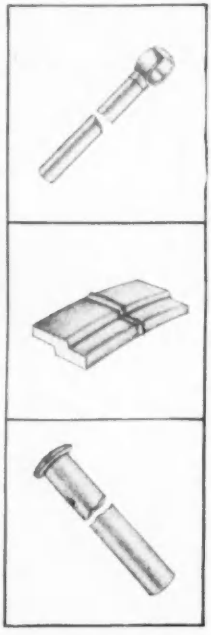

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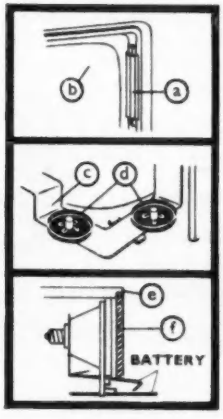

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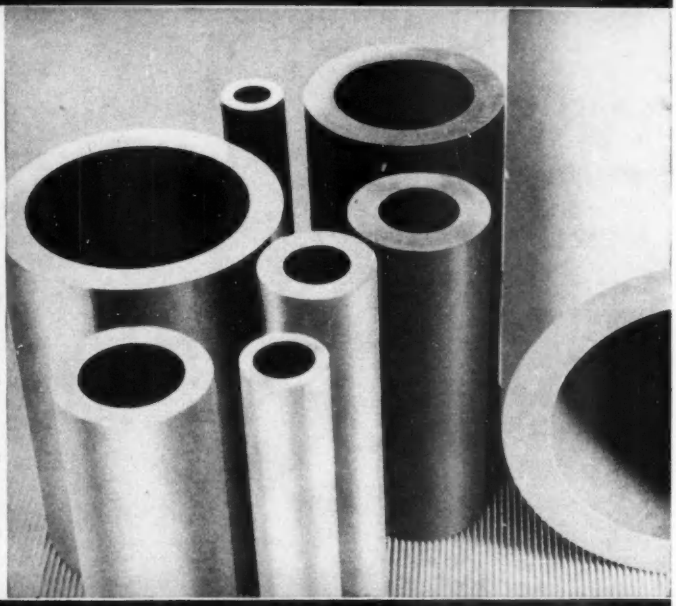

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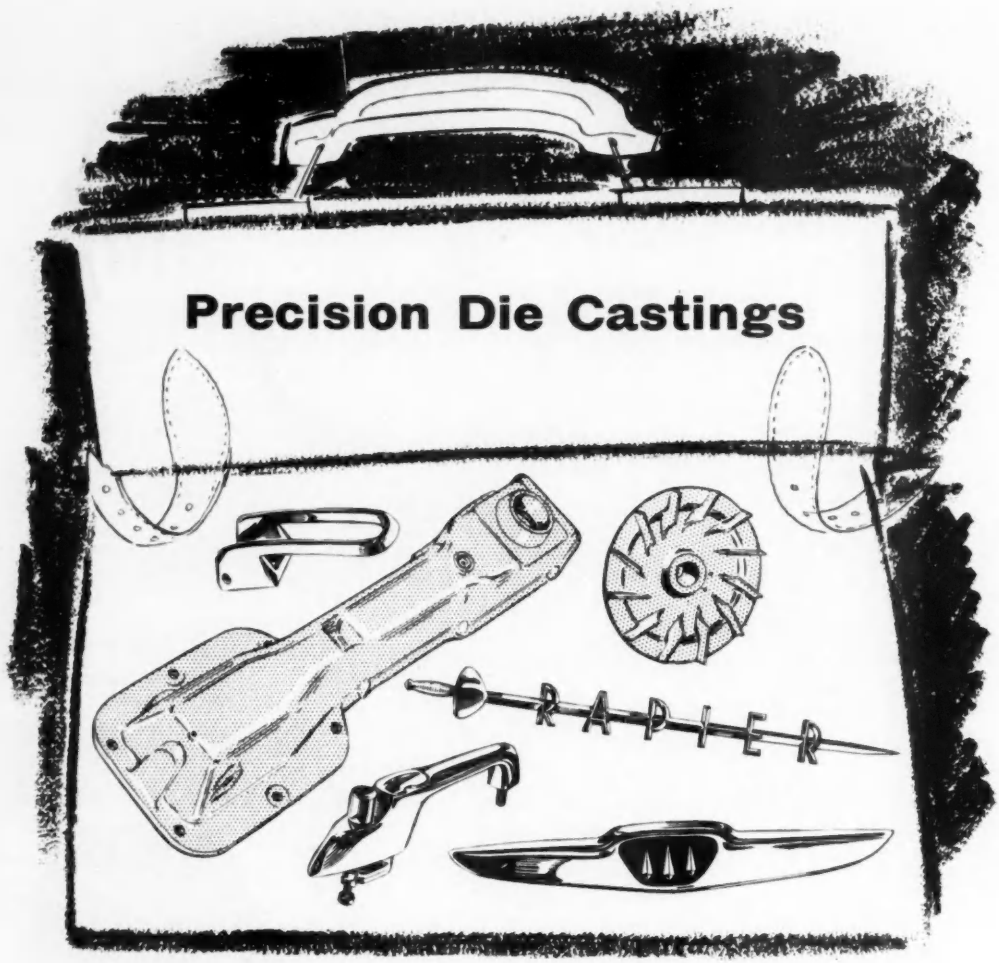

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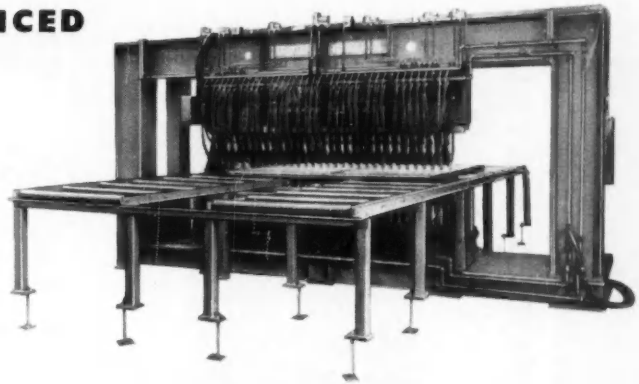

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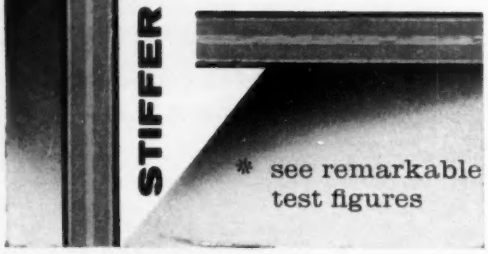

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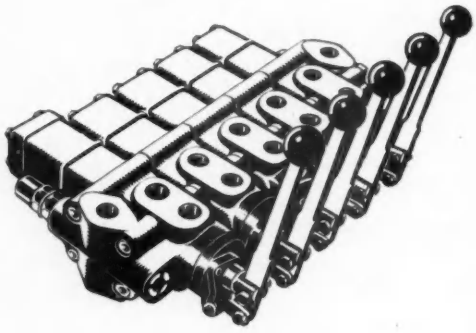

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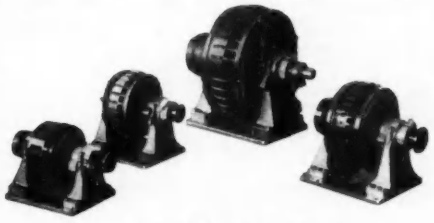

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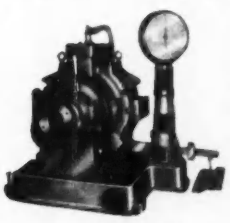

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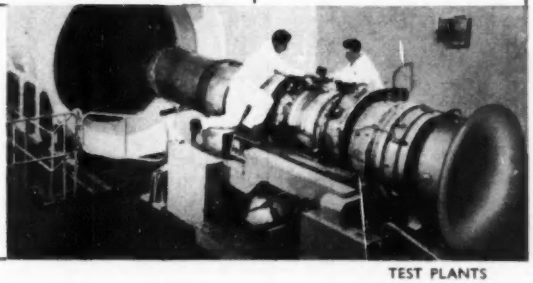

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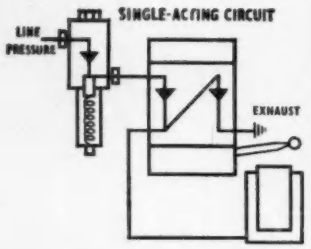

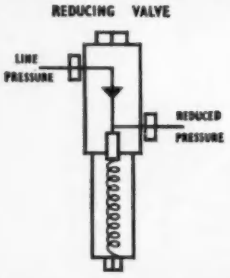

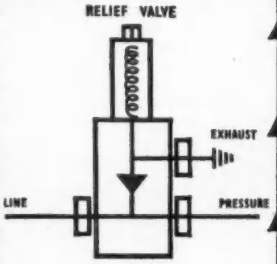

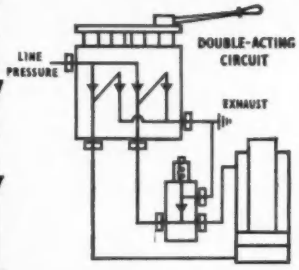

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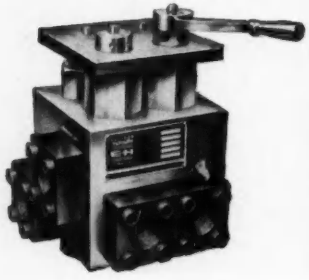

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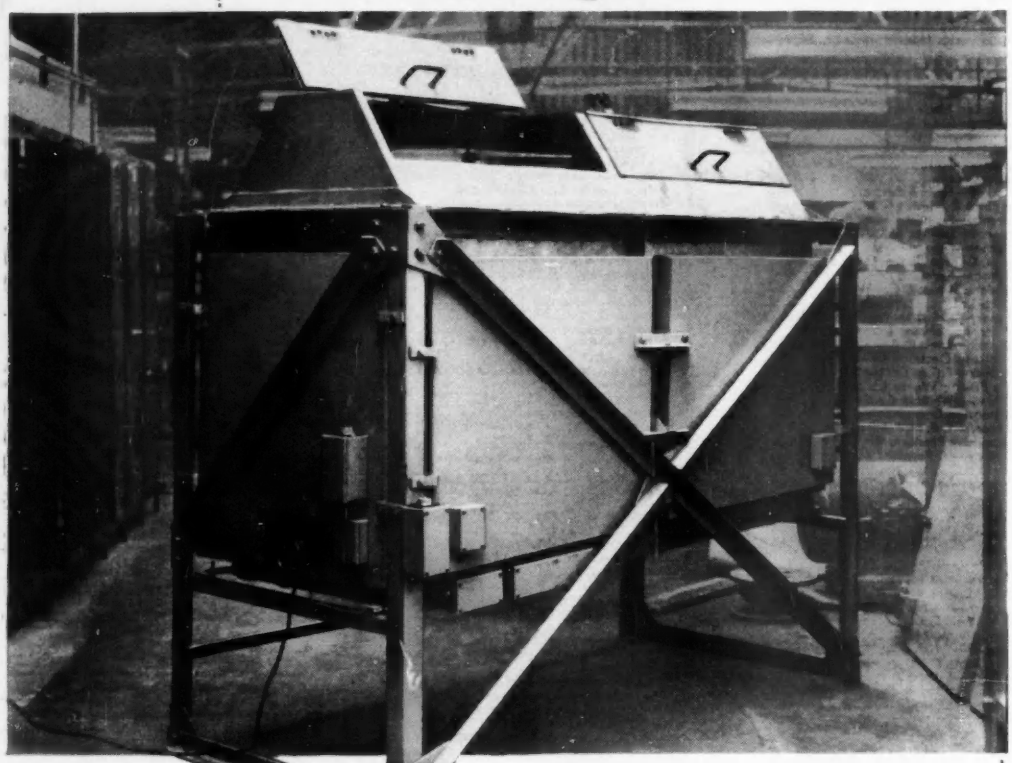

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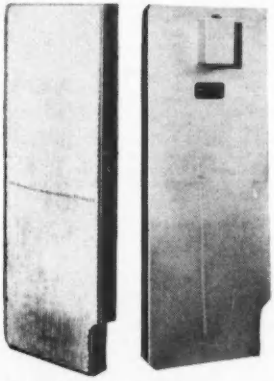

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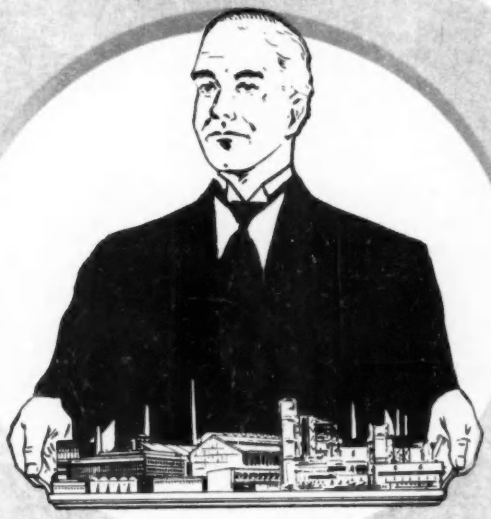

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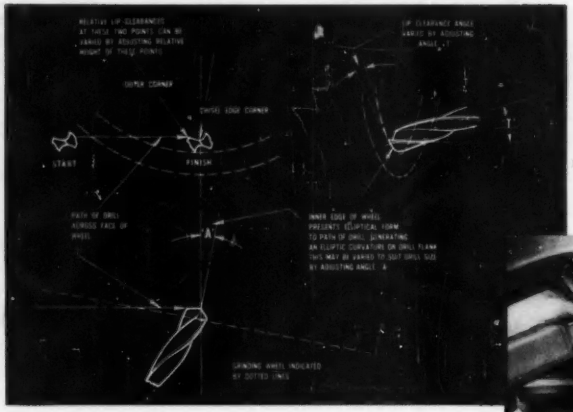
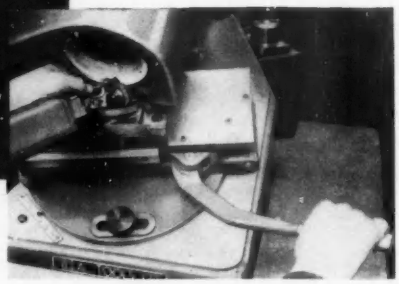


perfect drill point geometry for accurate holes

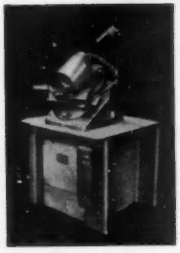


THE GRINDING PROCESS—*to simplify setting a chart provided gives angles 'A' and 'T' for various diameters. Flexibility of method allows point geometry to be varied as desired. The amount of metal removal can be pre-set by simple fine-screw adjustment to the axial position of the drill. Grinding is effected by a simple reciprocating movement.*

for sharpening right-hand 2-flute drills, parallel or taper shank, 1/16" - 1/2" (1.5 - 13mm) dia.

MAXIMUM ECONOMY IN WHEEL REPLACEMENT

Replacement grinding wheels can be cemented on to the non-expendable backplate by wheel suppliers at moderate cost. A 60-grit wheel supplied with the machine covers the whole range of drill sizes dealt with. For continuous grinding of the smaller sizes of drills an 80-grit wheel can be supplied.



Brochure describing the machine and method on request.

Enables perfect drill points to be produced, to suit any requirements, speedily and with unskilled labour, No collets or guide bushings required. Soft wheel — does not burn drill — no coolant necessary. Stepped drills and drill reamers handled equally well.

DRILL POINTING MACHINE

B.S.A. No. 0

B.S.A. Drill Pointing Machine No. 0

Motor : ½ h.p. 2850 r.p.m.
Weight : (with pedestal base & dust extraction unit) 476lb. (216 kg)
Floor space occupied : 33" × 33" × 52" high (840 × 840 × 1320 mm).

B.S.A. TOOLS LIMITED BIRMINGHAM 33 · ENGLAND
Cables : MADRICUT BIRMINGHAM TELEX 33-207.

AD. No. 506

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